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The Cardiovascular Effects of Resistance Exercise Training
and Orthostatic Intolerance In Elderly Individuals

A Thesis Presented to the Faculty of the Department of
Physical Education, Exercise and Sports Sciences
East Tennessee State University

In Partial Fulfillment of the Requirements for the Degree
Master of Arts in Exercise Science

by

Lynn Rhea

May 2001

Dr. Lynn Panton, Chair
Dr. Kathy Browder, Committee Member
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Keywords: orthostatic intolerance, elderly,
cardiovascular, tilt test, resistance training

ABSTRACT

The Cardiovascular Effects Of Resistance Exercise Training On Orthostatic Intolerance In Elderly Individuals

by

Lynn Rhea

One of the age-related changes associated with normal aging is the inability to maintain normal blood pressure homeostasis, a common clinical condition known as orthostatic intolerance. There are little data on the effects of strength training in healthy adults and orthostatic intolerance and only one study on strength training and elderly adults diagnosed with orthostatic intolerance. Therefore, the purpose of the present study was to evaluate the effects of resistance training on the cardiovascular responses of elderly individuals during an orthostatic challenge.

Thirteen subjects were assigned to either a resistance (RES; $n=7$; 66 ± 5 yrs.) or a control (CON; $n=6$; 71 ± 6 yrs.) group. During the 12-week treatment period, the RES trained 2x/wk, while the CON was asked not to change their normal lifestyles. The resistance training consisted of 3 sets of 8-12 repetitions using 12 machines at approximately 22% to 57% of 1RM. Before and after the training and control period, subjects were tested using a 70° head-up tilt. Tilt consisted of 30 minutes of supine rest while heart rate (HR) was recorded every minute and blood pressure (BP) was taken every 5 minutes. After the rest period, subjects were tilted to 70° for 30 minutes unless subjects experienced presyncopal symptoms. During the tilt period, HR and BP were recorded every minute. After the tilt, subjects were placed in a supine position for 15 minutes of recovery, HR was taken every minute and BP was taken every 5 minutes. A 2X2X8 (test X group X time) Repeated Measures Analysis of Variance was used to analyze data. Significance was accepted at $p\leq 0.05$.

After the 12 weeks of training, the RES significantly increased upper (46 ± 24 to 55 ± 29 kg) and lower (62 ± 20 to 80 ± 31 kg) body strength while the CON showed no changes. Body composition measurements by DEXA showed lean mass to increase significantly (50.5 ± 12.9 to 52.7 ± 13.1 kg) for the RES group, while the CON had no changes. Of the 13 subjects only 9 subjects completed the pre and post tilt tests. Of the 9 completing both tilt periods, there were no significant differences between groups for any of the dependent measures of HR, systolic blood pressure, diastolic blood pressure, and mean arterial pressure. In conclusion, this study demonstrated that a resistance training program was well tolerated and improved strength and lean mass in the RES. However, training did not help these individuals improve cardiovascular responses to an orthostatic challenge.

DEDICATION

This thesis is dedicated to my loving husband Chip. With his encouraging words, inspiration, and many hours of help, I was able to complete this project. I would also like to thank my parents Mike and Paulette Petty, they have also been right beside me throughout this experience, giving me their caring wisdom and advice that has helped me to pursue this degree. Thank you.

ACKNOWLEDGEMENTS

I would like to acknowledge the members of my thesis committee. First, I would like to thank my chairperson, Dr. Lynn Panton. Her patience and diligence are greatly appreciated in guiding me through this experience. I would also like to thank Dr. Craig Broeder and Dr. Kathy Browder for their encouragement and editorial contributions. Last, I would like to send a sincere thank you to all the subjects who volunteered to participate in this study, without their dedication this study would not have been able to take place. Thank you.

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CHAPTER 1

INTRODUCTION

In the next 10 years America's 50-something population is projected to expand by 12 million persons, rising from 25.3 million in 1996 to 37.7 million in 2006. This growth would represent more than half the nation's total population increase during the decade (U.S. Census Bureau, 1996). The American College of Sports Medicine (1998) reported that by the year 2030, the number of individuals 65 years and over will reach 70 million in the United States alone. In addition, persons 85 years and over will be the fastest growing segment of the population. As more individuals live longer, it is imperative to determine the extent and mechanisms by which exercise and physical activity can improve health, functional capacity, quality of life, and independence in this population.

There are many changes that occur as a person ages. For example, many elderly people have age-related loss in physiologic capacities which can be contributed to the decline in physical activity in this population (Cress et al., 1999). In fact, two-thirds of all adults age 65 years and older are either irregularly active or completely sedentary (Rooney, 1993). With this inactivity comes an increased risk of chronic diseases, including coronary heart disease, hypertension, diabetes, osteoporosis, and depression. However, research has indicated that participation in a regular exercise program is an effective intervention/modality to reduce and prevent a number of functional declines associated with aging (American College of Sports Medicine, 1998). Furthermore, the trainability of older adults is evidenced by their ability to adapt and respond to both endurance and strength training (American College of Sports Medicine, 1998). Exercise started as late as the age of 60 years is associated with a one to two

year increase in life expectancy, as well as increased functional independence (Rooney, 1993).

One of the age-related changes associated with normal aging is the inability to maintain normal blood pressure homeostasis. A common clinical condition associated with blood pressure in the elderly is orthostatic hypotension, which is a significant change in blood pressure when going from a supine position to standing position (Lipsitz, 1989). In a study on nursing home residents older than 60 years, blood pressure dropped 10% to 40% when the individuals first stood up in the morning. With this drop in blood pressure on standing, dizziness can occur which can ultimately lead to a fall (Health News, 1997). A study of community dwelling elderly populations showed a prevalence of this postural hypotension to be around 20-30%. The prevalence has been reported to increase with advancing age and decreases in basal blood pressure (Caird, Andrews, & Kennedy, 1973).

The baroreflex arc is important in enabling people to function in the upright position, as it is the principle mechanism responsible for short-term blood pressure control. Blood pressure sensors in the carotid and aortic arch are linked through glossopharyngeal and vagal nerves to central processing centers in the brainstem, which modulate efferent sympathetic and parasympathetic nervous activity to the heart. Through this mechanism, falls in blood pressure result in reflex vasoconstriction and increased heart rate and stroke volume (Ford, 1999). With advancing age, there is a decline in baroreflex sensitivity to both hyper- and hypotensive stimuli (Lipsitz, 1990). There may also be a decrease in the efferent baroreceptor-mediated responsiveness of heart rate acceleration during hypotensive stimuli (Gribbin, Pickering, Sleight & Peto, 1971). A decrease in cardiac compliance in the elderly may also limit the ability of the heart to increase end-diastolic volume and/or decrease end-systolic volume, thereby resulting in a decreased ability to compensate for declines in cardioacceleration capacity by way of an

increase in stroke volume (Shannon, Maher, Santinga, Royal, & Wei, 1991). Finally, a decrease in vascular compliance may lead to diastolic blood pressure or peripheral resistance responses to orthostasis that are not easily modified (Sowers, 1987).

Investigations involving young subjects have found that strength trained individuals appear to have increased protection against orthostatic hypotension due to an increased baroreflex sensitivity (Greenleaf et al., 1975), increased stroke volume and cardiac output (Smith & Raven, 1986), and/or increased muscular capability to support venous return which minimizes venous pooling (Epperson, Burton, & Bernauer, 1982; Epperson, Burton, & Bernauer, 1985; Tesch, Hjort, & Balldin, 1983). In contrast there are little data on the effects of strength training in healthy adults (Bleil, Panton, Stephens, & Franke, 1996; Carrol, Convertino, Pollock, Graves & Lowenthal, 1995) and only one study on strength training and elderly adults diagnosed with orthostatic intolerance (Brilla, Stephens, Knutzen, & Caine, 1998). Therefore, the purpose of the present study was to evaluate the effects of resistance training on the cardiovascular responses of orthostatically intolerant elderly individuals.

Statement of the Problem

Research studying the effects of resistance exercise training and orthostatic tolerance in older individuals is limited. Younger individuals who have strength trained have shown an increased protection against orthostatic hypotension. Therefore, if strength training can improve cardiovascular responses to an orthostatic stress, then falls that are due to hypotension in the elderly may be prevented. The purpose of this study was to examine the effects of resistance training on the cardiovascular responses of elderly men and women during an orthostatic

challenge. The orthostatic challenge that was used in this study to determine cardiovascular responses was a 70° head-up tilt test.

Research Hypothesis

The research hypothesis is that chronic resistive exercise will improve heart rate and blood pressure responses to 70° head-up tilt in orthostatically intolerant elderly individuals.

Delimitations

The subjects were recruited through newspaper advertisements and flyers in Johnson City and Washington County areas to be participants in the study. The sample included 2 men and 11 women, who were between the ages of 60 to 80 years. The study started in the summer of 2000.

The subjects included in the study exhibited no evidence of any medical conditions that would decrease the validity of orthostatic testing or resistance training. A pretest was administered on the subjects to assess their cardiovascular responses to an orthostatic stress before exercise training. The assessment of the cardiovascular responses of heart rate and blood pressure were measured with the subjects in a supine position on a motorized tilt table for 30 minutes. The 30 minute tilt period began once the subject was placed in a 70° head-up position. Following completion or discontinuance of the tilt portion of the test, the subject was returned to the supine position for a 15 minute recovery period. After testing was completed, subjects were assigned either to a control group or to a resistance-training group. After the 12 weeks of training or control period all subjects were reevaluated.

Subjects assigned to the treatment group performed resistance exercise training two times per week for 12 weeks. Subjects in this group trained with Cybex™ resistance machines

designed to exercise the major muscle groups of the body. The 6 subjects assigned to the control group were asked not to change their lifestyles during the 12 weeks of the study.

Assumptions

Within this study, the following assumptions were made:

1. Subjects in the control group did not dramatically alter their lifestyles during the 12 weeks of the study.
2. Participants in the strength-training group gave their best efforts during strength testing and training.

Limitations

The results from this study that involved a sample from the Johnson City and Washington County area, may not be applicable to other populations. Selection bias is a problem in this study because the subjects self-selected themselves to participate in the study. The sample may not be representative of the general population.

Definition of Terms

1. Orthostatic Hypotension: A significant drop (≥ 20 mmHg) in blood pressure when going from a supine position to standing position (Lipsitz, 1989).
2. Baroreflex / Baroreceptors: Pressure-sensitive receptors located in the aortic arch and carotid sinus. These receptors tonically inhibit sympathetic outflow from the cardiovascular center and respond to changes in blood pressure (McArdle, Katch, & Katch, 1996).
3. Stroke Volume: The quantity of blood ejected with each beat of the heart (McArdle et al., 1996).

4. Cardiac Output: The amount of blood pumped by the heart, usually during a one-minute period (McArdle et al., 1996).
5. One Repetition Maximum (1-RM): The maximum amount of weight lifted one time with correct form during a standard weightlifting exercise (McArdle et al., 1996).
6. Compliance: The change in vessel volume caused by a given change in pressure difference across the vessel wall; i.e. the greater the vessel compliance, the more stretchable the vessel wall (Vander, Sherman & Luciano, 1985).

CHAPTER 2

REVIEW OF LITERATURE

Introduction

Aging is a complex process involving many variables, such as genetics, lifestyle factors, and chronic diseases. The variables involved in aging interact with one another to greatly influence the manner in which we age (American College of Sports Medicine, 1998). There are many mechanisms that contribute to the understanding of the structural and functional changes that occur with normal aging. Advancing age is associated with decreased cardiac output which partly reflects decreased demand and reduced skeletal-muscle mass. Aging is also related to the prolongation of myocardial relaxation time and increased stiffness of the myocardium, both of which hinder ventricular filling and contribute to higher left ventricular diastolic pressures at rest and during exercise in older individuals (Wei, 1992). Some other problems associated with aging are decreases in muscle strength and mass, functional capacity, energy metabolism, protein intake, postural stability, flexibility, central nervous system function, cognitive function, and physical activity (American College of Sports Medicine, 1998).

Many of the age-related losses in physiologic capacities that elderly people experience can be attributed to their decline in physical activity (Cress et al., 1999). With the decline in physical activity comes an increased risk of chronic diseases, including coronary heart disease, hypertension, diabetes, osteoporosis, and depression. However, research has indicated that participation in a regular exercise program is an effective intervention/modality to reduce and prevent a number of functional declines associated with aging (American College of Sports Medicine, 1998).

Normal aging is associated with changes in the cardiovascular system, such as abnormalities in blood pressure homeostasis. A common clinical condition associated with abnormal blood pressure in the elderly is orthostatic hypotension, referred to as orthostatic intolerance, which is a significant decrease in blood pressure (≥ 20 mmHg) when going from a supine position to a standing position (Lipsitz, 1989). The occurrence of orthostatic hypotension has been found to be more prevalent in the morning when individuals first arise and when supine blood pressure is highest (Ooi, Barrett, Hossain, Kelley-Gagnon, & Lipsitz, 1997). Caird et al. (1996) examined the prevalence of orthostatic hypotension among elderly individuals to determine whether this condition would be a significant risk factor for related injuries such as falls. Caird et al. measured blood pressure in the supine position and after one minute's quiet standing in 494 people aged 65 or older that lived at home. On standing, a decrease in systolic pressure of 20 mmHg was found in 24% of the subjects. A decrease of 30 mmHg occurred in 9%, and a decrease of 40 mmHg occurred in 5% of the subjects. Caird et al. found that orthostatic hypotension is prevalent among the elderly and speculated that it could be a cause of falls leading to fractures in this population. In another study Cunha, Costa, Faria, and Carneiro (1991) determined the prevalence of orthostatic hypotension in elderly inpatients. One hundred elderly patients aged 60 and over were investigated. Cunha et al. (1991) measured supine (after resting for 30 minutes) and one, two, three, four, and five minutes standing blood pressures. Orthostatic hypotension was defined in this study as a decrease in systolic blood pressure of 20 mmHg or more. Cunha et al. (1991) determined that the prevalence of orthostatic hypotension was 30% among the 100 patients who participated in the study.

Orthostatic intolerance occurs as a result of the inability of the body's circulatory system to adjust to the upright posture. When an individual with orthostatic intolerance assumes the

standing position from a supine position, there is a sudden decrease in venous return to the heart. A decrease in venous return is caused by a decrease in central blood volume and increased venous pooling (Brooks, Fahey, White, & Baldwin, 2000). In the standing position, about 75% of the circulating blood is immediately shifted below the heart, with most of this volume shifting to the veins. This blood is pooled in the deep veins of the legs and pelvic region. The initial physiological changes that the body undergoes include decreases in venous return, cardiac filling pressure, stroke volume, mean arterial pressure, and cardiac output. Normally, mean arterial pressure and dizziness that occur during standing can be prevented by two mechanisms (Smith, 1994). First, mechanical compression of the veins of the legs by muscle contraction reduce the pooling of blood in the legs, thereby minimizing the decrease in venous return, cardiac output, and mean arterial pressure (Smith, Hudson, & Raven, 1987). Second, baroreceptors or baroreflex-mediated sympathetic excitation and parasympathetic vagal withdrawal leads to vasoconstriction and increase in heart rate (Smith, 1994).

The baroreceptors, which aid in vasoconstriction, are stretch receptors located in the heart, major arteries, and pulmonary vessels. The baroreceptors influence the cardiovascular control center affecting heart rate, cardiac contractility, and vascular resistance and compliance. They are involved in the short-term as well as long-term control of blood pressure regulation. When an individual stands up from either a supine or sitting position, the drop in blood pressure is detected by the baroreceptors. The baroreceptors in the wall of the carotid artery detect the degree to which the artery is distended by the blood. This means that the baroreceptors help detect changes in blood pressure and blood volume and, therefore, send the information to the lower brainstem. The lower brainstem responds by stimulating the sympathetic nervous system, resulting in the stimulation of the heart by the sympathetic nerves through the release of

catecholamines. In addition, the constriction of the blood vessels to increase blood pressure also occurs by sympathetic stimulation from the lower brainstem. The vasoconstriction that occurs in healthy individuals leads to a significant rise in systemic vascular resistance, which initially matches the decrease in cardiac output causing mean arterial pressure to remain unchanged. However, in an individual with orthostatic intolerance, blood pressure will drop due to the lack of vasoconstriction caused by a decrease in the sensitivity of the baroreceptors (Smith, 1994), or the inability of the veins to facilitate venous return.

Both age and hypertension impair baroreflex sensitivity, compliance of the heart and vasculature, and the ability to support venous return (Lipsitz, 1989). The vascular alterations due to atherosclerosis consist of changes in the structure of the arteries, causing vascular stiffness (Marin, 1995). Arteriosclerotic changes in the arterial walls in connection with the aging process, causes a decrease in baroreceptor sensitivity (Berkman, Magnier, Tran, & Demy, 1980). Loss of muscle mass and increased compliance may limit the ability to prevent venous pooling. These changes may cumulatively produce alterations in the blood pressure regulatory mechanisms that impair an older person's ability to adapt to hypotensive stress (Moss, 1993).

It has been suggested that strength training may play a role in alleviating problems of orthostatic tolerance in older subjects due to improvements in venous tone and enhanced baroreflex responses (Brilla et al., 1998). However, most studies examining the effects of resistance training and orthostatic tolerance have been in the younger population. This chapter will review the studies and mechanisms involved with young subjects followed by studies examining older subjects and orthostatic intolerance.

Cardiovascular Responses to Orthostatic Challenges with Resistance Training

Many mechanisms have been proposed to determine the system or systems that control cardiovascular responses to an orthostatic challenge. The studies that have examined these mechanisms have used lower body negative pressure (LBNP), tilt challenges, and stand tests to try to determine cardiovascular responses to an orthostatic change. Many of the results are conflicting due to differences in methodology and differences in subject populations. Since the early 1970s LBNP tests have been used to simulate the pull of gravity. The test involves an individual entering a four-foot air-tight fabric covered cylinder that seals just below the waist. The air inside the cylinder is removed to create negative pressure to imitate the “pull” of gravity. The LBNP test stimulates the effects of gravity and “pulls” fluids to the lower body. Tilt table testing involves strapping an individual to a table horizontally which has a foot board at the end to stand on. The straps that are placed around the individual are to keep individuals from falling. The table is then tilted to a 70° position (near standing). The table remains in the standing position for 30 minutes or until orthostatic hypotensive symptoms occur. In the event that an individual becomes symptomatic, the table would then be placed back to the supine position allowing the subject to recover. Stand tests involve subjects being tested for resting heart rate and blood pressure in the supine, sitting, and standing positions. Then the same measurements are taken when subjects rise from a cot after a 10-minute rest period, and rise from a chair after a five-minute rest period. All three tests are used to evaluate whether or not an individual experiences orthostatic intolerance.

Smith and Raven (1986) examined the cardiovascular responses to LBNP in eight sedentary untrained control (UT) subjects (27.4 ± 1.2 years; $\dot{V}O_{2\max} = 38.8 \pm 2.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), eight endurance trained (ET) subjects (27.9 ± 1.4 years; $\dot{V}O_{2\max} = 62.0 \pm 2.0 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), and

eight experienced weight trained (WT) subjects (23.0 ± 1.1 years; $\dot{V}O_{2\max} = 43.5 \pm 2.6 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). The ET subjects had been involved in running competitively for three or more years and averaged >50 miles/week in their training routines. The WT group had competed in state or national AAU-sanctioned power-lifting meets. The researchers used the results to compare and contrast the blood pressure control system of these three groups from rest to -50 torr of LBNP.

Although not statistically significant, Smith and Raven (1986) proposed that the WT subjects elicited a more effective maintenance of SBP during LBNP (SBP rest = 115.0 ± 3.0 mmHg, SBP -50 torr = 102.2 ± 2.7 mmHg) compared to ET (SBP rest = 125.8 ± 1.8 mmHg, SBP -50 torr = 105.0 ± 3.0 mmHg) and (UT) (SBP rest = 124.8 ± 3.3 mmHg SBP -50 torr = 105.5 ± 4.5 mmHg) by reason of greater stroke volume and cardiac output. Peripheral vascular resistances were not different throughout LBNP among the three groups (WT rest = $14.9 \pm 1.7 \mu$, -50 torr = $16.7 \pm 1.6 \mu$; ET rest = $15.7 \pm 1.6 \mu$, -50 torr = $20.5 \pm 1.8 \mu$; UT rest = $17.3 \pm 1.7 \mu$, -50 torr = $21.7 \pm 1.3 \mu$), suggesting that the maintenance of blood pressure may have been due to a cardiac effect. The ET subjects during the study had a greater percentage of pooling of blood in the leg at -50 torr compared to rest (Leg Volume WT rest = 10.42 ± 0.31 l, -50 torr = 10.83 ± 0.31 l; ET rest = 7.83 ± 0.61 l, -50 torr = 8.15 ± 0.61 l*; UT rest = 9.58 ± 0.61 l, -50 torr = 9.88 ± 0.51 l) and lower baroreflex sensitivity ($\Delta\text{HR}/\Delta\text{SBP}$ for LBNP from rest to -50 torr); WT = 1.51 ± 0.24 , ET = $0.99 \pm 0.20^*$, UT = 1.38 ± 0.14) than the UT or WT subjects (* $p < 0.05$).

In another study Tatro, Dudley, and Convertino (1992) examined the effects of lower body resistance training on cardiovascular control mechanisms and blood pressure maintenance during an orthostatic challenge to presyncopal conditions. Lower body negative pressure was used to test orthostatic intolerance, carotid-cardiac baroreflex function (using neck chamber

pressure), and calf compliance. These measures were taken on eight healthy normotensive males (32 ± 3 years) before and after 19 weeks of resistance training. Resistance training exercises performed during the study were the bilateral supine leg press followed by unilateral seated knee extension. Subjects performed four sets of 10-12 repetitions of each exercise during the first 7 weeks of training, four sets of 8-10 repetitions during the next 6 weeks, and five sets of 6-8 repetitions during the last 6 weeks. The load was adjusted to result in failure to lift the weight within the prescribed number of repetitions for each set. Three minutes of rest were given between sets and subjects completed at least 34 of the 38 training sessions. The 3-repetition maximum test (3RM) was determined within five to seven sets: one set of three repetitions at 60, 70, and 80% of estimated 3RM. The load was increased until three repetitions could not be performed.

Tatro et al. (1992) indicated that resistance training resulted in increases in strength and muscle fiber size. The 3RM leg press increased ($p=0.0003$) from 150 kg to 180 kg, and the knee extension 3RM increased from 65 kg to 82 kg after training ($p=0.0004$). Muscle hypertrophy was indicated by an increase of $4600 \mu\text{m}^2$ to $5300 \mu\text{m}^2$ in average muscle fiber size ($p=0.0014$). Although muscle size and strength increased, lower extremity strength did not contribute to changes in cardiac, hemodynamic, or vasoactive endocrine responses to LBNP.

Tatro et al. (1992) found several factors associated with blood pressure control that were altered during training. The stimulus response relationship of the carotid-cardiac baroreflex response shifted to the left on the carotid pressure axis as indicated by a reduction in baseline systolic blood pressure (125 ± 2 mmHg to 119 ± 3 mmHg). In addition, maximum slope increased ($5.4 \pm 1.3 \text{ ms}\cdot\text{mmHg}^{-1}$ before training to $6.6 \pm 1.6 \text{ ms}\cdot\text{mmHg}^{-1}$), and heart rate

variability increased. Calf compliance decreased in five of seven subjects measured from pretraining mean of 4.4 ± 0.6 ml·min Hg⁻¹ to posttraining mean of 3.9 ± 0.3 ml·min Hg⁻¹.

Tatro et al. (1992) suggested that high resistance, lower extremity exercise training may cause a chronic increase in sensitivity and resetting of the carotid-cardiac baroreflex. However, these subtle changes in carotid-cardiac baroreflex function, heart rate variability, and calf compliance did not alter cardiovascular responses to the orthostatic challenge or alter LBNP tolerance to presyncope conditions.

The results reported by Tatro et al. (1992) are in conflict with those of Smith and Raven (1986). Smith and Raven compared cardiovascular responses to LBNP in untrained, endurance trained, and weight trained subjects. They reported that the weight-trained subjects were able to maintain blood pressure at -50 mmHg LBNP due to better maintenance of stroke volume and cardiac output while Tatro et al. reported no improvements in blood pressure maintenance during LBNP. The difference in the results of the two studies may be due to the fact that the weight trained subjects used by Smith and Raven were competitive power lifters at the state and national level and had much greater resting stroke volumes than the control subjects used by Tatro et al. Therefore, chronic resistance training over many years may evoke cardiovascular adaptations that do not take place in only 19 weeks. The study by Smith and Raven was also cross-sectional and can not take into account genetic differences among the three groups. The weight trained subjects used by Smith and Raven were competitive power lifters. As a result, the reason for the better ability to maintain systolic blood pressure due to better maintenance of stroke volume and cardiac output may be a genetic effect that these competitive power lifters possess. Another problem with the study by Tatro et al. is that the subjects resistance-trained only the lower body. Lightfoot, Torok, Journell, Turner, and Claytor (1994) hypothesized that whole body resistance

training would increase tolerance to LBNP better than lower body training. It is possible that multiple muscle group training may alter muscle compliance and cardiac function more than single muscle group training.

In another study, Lightfoot et al. (1994) compared cardiovascular responses and LBNP tolerance of sedentary individuals undergoing a 12-week full body resistance training program with chronic weight lifters. Twelve subjects (19.6 ± 0.4 years; $V_{O_2\max}=51.5 \pm 1.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) were placed in the resistance training group, eight subjects (25.4 ± 2.4 years; $V_{O_2\max}=50.8 \pm 2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) served as a control group, and five subjects (22.4 ± 0.9 years; $V_{O_2\max}=56.1 \pm 1.8 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) who were body builders that had chronically resistance trained for at least four years, were recruited as the third group. Each subject in the resistance training group participated in three supervised resistance training sessions per week for 12 weeks. During each training session, each subject completed four to five sets of the following isotonic exercises: squats, leg press, calf raises, leg extensions, leg curls, weighted sit-ups, bench press, military press, lateral pull-overs, dumbbell flies, biceps curls, and triceps extensions. Each set consisted of five to eight repetitions with the resistance being increased when the subject was able to complete eight repetitions.

Before resistance training the control group had significantly higher strength levels than the acute resistance training group in the quadriceps (133.9 ± 15.6 vs $100.3 \pm 4.1 \text{ N}\cdot\text{m}$; $p<0.05$), hamstrings (85.5 ± 6.1 vs $61.7 \pm 2.1 \text{ N}\cdot\text{m}$; $p<0.05$), and gastrocnemius (82.4 ± 8.0 vs $46.8 \pm 5.2 \text{ N}\cdot\text{m}$; $p<0.05$). After the 12-week training program, the acute resistance trained group showed a 58% increase in quadriceps strength, a 55% increase in hamstring strength, and a 111% increase in gastrocnemius strength. The control group did not exhibit any significant changes in torque in the three muscle groups. After resistance training, the acute resistance trained group's

LBNP tolerance significantly increased by 8% (-78 mmHg to -83 mmHg) while the control groups LBNP tolerance was not altered by the 12-week period. The chronically resistance trained group's LBNP tolerance to presyncopal symptoms was 17% higher (-93mmHg) than the control group and 12% higher than the resistance trained group after the 12-week period.

Lightfoot et al. (1994) indicated no significant changes in heart rate for the acute resistance trained group (65 ± 3 to 64 ± 3 b/min), however, there were significant decreases ($p \leq 0.05$) in systolic and diastolic blood pressure (SBP: 131 ± 3 mmHg to 121 ± 2 mmHg; DBP: 69 ± 3 mmHg to 65 ± 2 mmHg). Lightfoot et al. concluded that acute resistance training of multiple muscle groups causes small increases in LBNP tolerance while longer-term resistance training causes greater increases in LBNP tolerance. The small increase in LBNP tolerance for the acute resistance trained group may have been due to an alteration in vascular compliance. After resistance training, at the negative pressure that had been the pre-training maximal pressure, the acute resistance trained group pooled less blood in their legs. Additionally, the chronically resistance trained group's leg circumference response at the same negative pressure as the control group's maximal negative pressure pretraining, indicated no differences found in the amount of blood pooled. These findings indicated that at the same absolute negative pressures, acute resistance training decreases the amount of blood pooled in the legs. Therefore, the ability to maintain cardiac output and systemic arterial pressure during exposure to an orthostatic stress may be dependent on the amount of blood pooled in the lower extremities and the subsequent effect on venous return (Convertino, Doerr, Flores, Hoffler, & Buchanan, 1988). The mechanisms for the decrease in blood pooling in the legs after acute resistance training is unknown, however, it could be caused by muscle hypertrophy as a result of resistance training

that may have decreased venous compliance and capacitance. The mechanisms responsible for the greater increase in LBNP tolerance with chronic resistance training are unclear and require further research (Lightfoot et al.).

In a different modality for testing orthostasis, McCarthy et al. (1997) measured cardiovascular responses to standing and to pre-syncopal limited LBNP in two groups of healthy, sedentary, normotensive men. Subjects did not exercise for at least three months before the start of the study. The study consisted of a control group (29 ± 5 years) and a resistance exercise training group (34 ± 5 years). Blood volume, carotid baroreceptor reflex response, leg compliance, stand tests and LBNP tests were performed during a 2-week interval before, and within 1 week after the 12-week resistance training program or control period.

Exercise subjects trained on Mondays, Wednesdays, and Fridays for the 12-week period. The intensity, frequency, and duration of the training were designed to induce marked improvements in strength and muscle mass. The resistance training program stressed all major muscle groups and consisted of nine exercises, each performed for one warm-up set and three maximal effort sets. The warm-up set was performed using approximately 67% of the load lifted in the first maximal effort set for each exercise. The exercises performed using barbells included parallel squats, bench press, and standing curl. Resistance exercise machines (Cybex™ Strength Systems) were used for the remaining movements: horizontal leg press, leg curl, wide grip lateral pull-down, shoulder press, inclined heel raise, and seated heel raise. A sequential progression in load was incorporated within each week of training: session one, 11 repetition maximum (11 RM) (range 10-12 RM); session two, 7 RM (range 6-8 RM); and session three, 5 RM (range 4-6 RM). When a set was performed outside the desired range of repetitions, the load of subsequent

sets was adjusted accordingly. Rest periods between exercise sets were limited to 90 seconds. Subjects completed an average of 34.6 out of a possible 36 sessions (96% adherence).

There was not a significant change in LBNP tolerance in either the exercise-training group or the control group between pre and posttesting. All subjects completed the 10-minute stand test during pre and posttesting sessions without syncopal symptoms. The exercise group tended to have ($p < 0.06$) a higher pretesting supine resting heart rate (63 b/min) compared to the control group (57 b/min). The posttesting heart rates were reduced significantly in the exercise group both at rest and during standing (exercise pre rest = 63 b/min to post rest = 61 b/min, standing pre = 94 b/min to standing post = 87 b/min; control pre rest = 57 b/min to post rest = 57 b/min, standing pre = 99 b/min to standing post = 93 b/min), so that the posttesting heart rates of the two groups were similar. No significant pre to posttest differences were found for systolic, diastolic, mean arterial or pulse pressures at rest or during standing. For controls, pretesting blood pressures (systolic/diastolic) during the stand test were $119 \pm 3 / 74 \pm 2$ mmHg (supine) and $112 \pm 3 / 78 \pm 2$ mmHg (after 10 min of standing); posttesting blood pressure were $116 \pm 4 / 72 \pm 2$ mmHg (supine) and $108 \pm 3 / 77 \pm 3$ mmHg (after 10 min of standing). For the exercise group, pretesting blood pressures during the stand test were $117 \pm 3 / 79 \pm 2$ mmHg (supine) and $109 \pm 4 / 79 \pm 3$ mmHg (after 10 min of standing). Posttesting blood pressures were $115 \pm 2 / 74 \pm 2$ mmHg (supine) and $111 \pm 3 / 81 \pm 3$ mmHg (after 10 min of standing).

McCarthy et al. (1997) also wanted to determine whether whole-body resistance training could successfully expand blood volume and if this could contribute to an increase in LBNP tolerance. McCarthy et al. found that the exercise group had small significant elevations in blood volume (pre = 3133 ml to post = 3203 ml) following training (2.8% increase; $p = 0.001$).

Although this increase in blood volume was significant, it was not sufficient to induce a detectable improvement in LBNP tolerance or stand test responses.

The resistance training protocol used in this study produced substantial increases in 1RM strength (kg) (leg press 153.8 ± 5.9 to 168.3 ± 5.4 ; leg curl 79.9 ± 4.5 to 86.2 ± 4.8 ; bench press 67.1 ± 3.2 to 79.8 ± 3.3 ; heel raise 201.9 ± 8.1 to 231.8 ± 10.6); lean body mass (59.1 to 61.1 kg), and leg muscle volume (cm^3) (quadriceps 1165 ± 84 to 1334 ± 95 cm^3 , hamstrings 554 ± 40 to 584 ± 40 cm^3 , adductors 525 ± 37 to 569 ± 49 cm^3 , plantar flexors 799 ± 72 to 829 ± 72 cm^3 , anterior calf 582 ± 60 to 584 ± 56 cm^3). Despite these adaptations to resistance exercise, there were no improvements in LBNP tolerance or cardiovascular responses to standing LBNP (McCarthy et al., 1997). The reason for the lack of improvements in LBNP tolerance during this study may be because the subjects who volunteered to be in the exercise group had unusually high LBNP tolerances. Therefore, the effectiveness of resistance training to alter LBNP tolerance may depend upon the pretraining level of tolerance, where subjects with a high LBNP tolerance are less likely to exhibit an improvement following intervention (McCarthy et al., 1997).

Resistance Training and Cardiovascular Responses to an Orthostatic Challenge in Elderly Adults

There are very few studies evaluating elderly individuals and the effects of resistance training on cardiovascular responses to an orthostatic challenge. One of the first studies by Carroll et al. (1995) evaluated the effects of 6 months of exercise training on cardiovascular responses to head-up tilt (HUT) in the elderly. Seventy-one sedentary subjects (45 women, 26 men), ranging in age from 60 to 82 years, served as volunteers in the study. Of the 71 subjects

completing initial testing, 44 subjects (30 women, 14 men) completed the entire HUT protocol before and after 6 months of training. This study had three experimental groups, one group performed only endurance training on either a treadmill or a stair climbing machine. The other experimental group performed the same endurance training but added selected resistance training exercises to their program. The remaining nine subjects were placed in to a control group.

Endurance training for the two experimental groups consisted of three sessions per week for 26 weeks. All sessions had a 5- to 10-minute warm-up and cool-down. Initially, all subjects exercised for 20 minutes at 40-50% of their maximal heart rate reserve (HRR). Exercise duration was increased by 5 minutes every 2 weeks until exercise time was 40 minutes. After the fifth week, exercise intensity was increased gradually to 60-70% (HRR). Subjects involved in the endurance and resistance-training group performed one set of eight to 15 repetitions of biceps curl, triceps extension, and leg press, three times per week for the 26-week training period.

After the 6-month training period the endurance group increased $\dot{V}O_{2\max}$ by 16.2% ($21.6 \pm 4.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ to $25.1 \pm 5.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, $p \leq 0.05$). The endurance/resistance group increased $\dot{V}O_{2\max}$ by 12.3% ($24.3 \pm 5.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ to $27.3 \pm 5.6 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, $p \leq 0.05$). For the final values there were no differences between endurance and endurance/resistance trained groups for $\dot{V}O_{2\max}$. The pre and posttesting values for $\dot{V}O_{2\max}$ for the control group were not significantly different ($22.8 \pm 3.7 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and $21.6 \pm 4.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). The endurance/resistance group increased biceps (23.5 ± 10.8 to 29.5 ± 12.7 kg after training) and triceps strength (17.9 ± 7.7 to 22.6 ± 10.2 kg) by 25.3% and 26.1%, respectively, while the changes in the endurance (biceps: 16.0 ± 6.5 to 16.7 ± 7.5 kg; triceps: 13.5 ± 5.3 to 13.9 ± 5.5 kg) and control (biceps: 21.4 ± 10.3 to 21.0 ± 9.8 kg; triceps: 16.7 ± 7.7 to 16.3 ± 7.5 kg) groups were less than 5%. Before the 6-

month training period, the endurance/resistance-trained groups were stronger than the endurance trained group in the leg press. After the training, both the endurance trained (49.9 ± 30.0 to 59.4 ± 32.2 kg) and the endurance/resistance trained (87.3 ± 46.0 to 107.1 ± 53.9 kg) groups increased leg press strength by 19.1% and 22% ($p \leq 0.01$), respectively, and the control group showed no change.

The analysis evaluating the effect of training on cardiovascular responses to tilt indicated that there were no test by group interactions for heart rate, stroke volume, cardiac output, systolic blood pressure, diastolic blood pressure, mean arterial pressure, or total peripheral resistance. Carroll et al. (1995) suggested that the responses to head-up tilt were not altered either by endurance training alone or by endurance/resistance training. The training protocol used in this study may have contributed to the reason changes in orthostatic tolerance were not seen in the training groups. Only a few selected exercises were used in the training protocol (biceps, triceps, and leg extensions); therefore, there may not have been enough stimulus to elicit significant effects on orthostatic responses. If a larger number of muscle groups had been incorporated, there may have been a difference in cardiovascular responses to the HUT.

In another study with older adults, Bleil et al. (1996) examined the effects of a 12-week resistance-training program on cardiovascular responses during an orthostatic challenge. The study consisted of 10 control subjects (70 ± 1 years) and 11 resistance trained subjects (67 ± 2 years). The subjects who were included in the study passed an initial screening, were free from overt evidence of hypertension and coronary artery disease, and had no orthopedic or other medical conditions that would interfere with exercise testing or training. The strength-training group trained three times per week for 12 weeks. Exercises used during the study included the military press, chest press, biceps curls, triceps extensions, lower-back, abdominals, leg press,

leg curls, leg extensions, and calf raises. For all exercises except the calf raise, subjects performed 8-12 repetitions to failure for the first 2 weeks of training and three sets of eight repetitions thereafter. The resistance was increased by five pounds after the subject was able to complete three sets of eight repetitions on three consecutive days. For the calf raise, subjects performed three sets of 25. The subjects trained between 60-80% of their 1RM.

There was no difference in upper body strength during the 12-week study for the control group. The control group had significant increase ($6.0 \pm 2.4\%$) in lower body strength ($p < 0.05$). However, the trained group had significant increases ($p < 0.05$) in chest press (35.6 ± 4.2 to 48.9 ± 5.9 kg) and in leg extensions (38.6 ± 4.3 to 54.4 ± 5.6 kg) when compared to the control group. Neither the sum of seven skin folds or body weight changed for either the control group or training group after the 12 weeks. The mean cross-sectional areas of both Type I ($4,203 \pm 423$ vs $5,248 \pm 611 \mu\text{m}^2$) and Type II ($3,375 \pm 363$ vs $4,286 \pm 669 \mu\text{m}^2$) muscle fibers were significantly increased after training ($p < 0.05$).

Forearm blood flow (FBF), forearm vascular conductance (FVC), mean arterial pressure (MAP) and heart rate (HR) responses to LBNP were not altered by the 12 weeks of resistance training. Bleil et al. (1996) concluded from the data that the cardiovascular responses of older individuals to LBNP are unaffected by 12 weeks of whole-body resistance training despite increases in muscle strength and size. Bleil et al. suggested that training-induced responses to an orthostatic challenge may differ in an older population because of age-related structural and physiological changes in the cardiovascular system. Therefore, an older population may be less likely to exhibit changes in orthostatic responses, despite significant training-induced improvements in other physiological systems (Bleil et al.).

One of the only studies to evaluate strength training on individuals with confirmed orthostatic hypotension was a study by Brilla et al. (1998). This study examined the frequency of orthostatic hypotension and the effect of a resistance training program in community dwelling older adults between the ages of 60-85 years old. The subjects participated in pretesting and posttesting sessions to determine the effects of a supervised 8-week strength-training program. All subjects were tested for resting blood pressure and heart rates in the supine, sitting, and standing positions. The response to orthostasis was evaluated by rising from a cot after 10 minutes in the supine position, and also by rising from a chair after five minutes of sitting.

All subjects were requested to attend three strength-training sessions per week for 8 weeks. Each training session began with a series of stretching exercises for the arms, legs, and trunk. The flexibility exercises included the back scratch test, horizontal flexion and extension for the shoulder, hip flexion and abduction/adduction from the supine position, knee flexion and extension, and plantarflexion and dorsiflexion. After the stretching routine, each subject performed eight exercises on weight machines. During the first week of the program, the subjects were instructed on lifting techniques, and performed 8 to 12 repetitions of each exercise using a small amount of resistance, 10 to 30 pounds; 20 repetitions were performed on the shuttle machine. One repetition maximum (1RM) for each exercise was determined the first week by having the subject select a weight that they could lift 8 to 20 times. The 1RM was then predicted using the equation $\text{weight lifted} / 1.0278$ ($0.0278 \cdot \text{No. of repetitions}$). The predicted 1RM was performed at one session and was used to determine the amount of weight for each lift. In the second week, subjects performed lifts using weights at 50% of their predicted 1RM. In weeks 3 through 8, the weights were increased to 80% of 1RM. The subjects completed one full set of each exercise, alternating in the order of upper and lower extremity exercises. The predicted

1RM was recalculated every 2 weeks during the program. The exercises performed included the bench press, triceps press, leg press, leg curl, hip flexion, hip abduction, hip adduction, plantarflexion, dorsiflexion, and the shuttle.

Significant changes in the group with impaired orthostatic tolerance were seen in supine diastolic blood pressure (DBP), which increased slightly (78.8 mmHg to 82.0 mmHg), sitting systolic blood pressure (SBP), which was slightly lower (147.1 to 143.2 mmHg), and standing heart rate (HR), which increased (70.8 b/min to 75.7 b/min). Orthostatism improved in both posture changes, rise from a cot (supine) and rise from a chair ($p < 0.05$). Significant increases were seen in DBP for both conditions (rise from cot DBP= 75.6 to 82.3 mmHg; rise from a chair DBP= 78.5 to 83.2 mmHg), and SBP and HR for the rise from the chair condition (SBP= 139.1 to 148.8 mmHg; HR= 73.8 to 77.0 b/min). The calculated mean arterial pressures for both rise from a cot (95 to 102 mmHg) and rise from a chair (98 to 104 mmHg) increased significantly ($p < 0.05$).

After the training there were significant increases in strength. The strength training may have contributed to the improvements of orthostatic hypotension by both mechanical and neural mechanisms. The strength gains, especially in the lower extremity may have helped the muscle action on vessel extraluminal tone and in venous return.

Brilla et al. (1998) indicated that previous research has noted that sympathetic nervous activity and baroreflex adjustments are enhanced with exercise. This change in neural activity may strengthen the probability of adequate responses to the change in posture and facilitate appropriate adjustments (Brilla et al.). This was the first study to evaluate orthostasis in a population of individuals with confirmed hypotension. Perhaps earlier studies that used healthy

adults were unable to find significant changes in orthostatic tolerance due to the higher quality of health that would limit the subjects to improve response to an orthostatic challenge.

Summary

In older individuals, orthostatic intolerance is associated with various mechanisms. The physiological responses to orthostasis are primarily a redistribution of blood volume and a decrease in blood pressure of approximately 20 mmHg or more. Initially, there is a decrease in venous return, cardiac filling pressure, stroke volume, mean arterial pressure, and cardiac output. In normal individuals, muscle contraction in the extremities and baroreflex-mediated sympathetic excitation aid in maintaining blood pressure. However, individuals who suffer from orthostatic intolerance are unable to control blood pressure due to one or both of these mechanisms. When an individual has orthostatic intolerance, functional capabilities in the upright position are impaired, which can ultimately lead to dizziness, syncope, or falls. To identify one variable as the principle cause is difficult and requires further research. A decrease in physical activity, which often occurs with advancing age and decreases in baroreflex sensitivity plays a major role in an individual's ability to maintain blood pressure.

Resistance training could possibly play an important role in helping to alleviate the symptoms associated with orthostatic hypotension in older individuals. Resistance training in younger individuals has been found to result in higher stroke volume and cardiac output during an orthostatic stress, therefore, aiding in maintaining blood pressure (Smith & Raven, 1986). However, the subjects who elicited these results were chronically resistance trained and this differs greatly from the subjects used in other studies. The training stimulus may also play a significant role in how subjects are able to maintain blood pressure during an orthostatic stress.

Subjects who resistance trained the entire body elicited small increases in tolerances to LBNP (Lightfoot et al. 1994), while Tatro et al. (1992) reported that those who resistance trained only the lower body, found no improvements in blood pressure maintenance during LBNP. The present study was performed to try to determine if subjects who experience dizziness when moving from a supine to standing position will benefit from a full body resistance training program.

Studies on older subjects and orthostatic intolerance are few. Brilla et al. (1998) who evaluated strength training on older individuals with confirmed orthostatic hypotension found improvements in cardiovascular responses after training. Brilla et al. used stand tests, which examine only the initial changes in cardiovascular responses from supine or sitting to standing. The tilt test protocol that was used in the present study was thought to perhaps better evaluate the cardiovascular responses over a 30-minute tilt period rather than stand tests that only evaluate the initial cardiovascular responses to standing.

CHAPTER 3

RESEARCH METHODS

Subjects

Subjects included 13 sedentary, elderly (60 to 80 years) individuals. The subjects were recruited from the Johnson City and Washington County area through the use of newspaper advertisements and flyers. Subjects had an initial visit to the laboratory where they completed medical history, demographic, physical activity, smoking, and nutrition questionnaires. The subjects also participated in cardiovascular and physical examinations administered by a physician. To be chosen for the study, subjects had to be free from any significant indications of hypertension (blood pressure exceeding 160/100 mmHg at rest), and orthopedic or other medical conditions that would preclude exercise testing or training. Subjects included in this study all self-reported symptoms of dizziness when moving from a supine or sitting position to a standing position. This study was approved by the Institutional Review Board at East Tennessee State University. All subjects were required to sign informed consents.

Procedures

Before and after training, all subjects were measured for maximal oxygen uptake ($\dot{V}O_{2\max}$), cardiovascular responses to 30 minutes of 70° head-up tilt, body composition, and strength. The $\dot{V}O_{2\max}$ test was also used to screen for cardiovascular disease. If any of the subjects had a positive stress test they were not allowed to participate in the study and were referred to a cardiologist for further evaluation. The subjects were monitored with a 12-lead EKG. Heart rate (HR) and blood pressure (BP) measurements were taken in the supine, sitting, and standing positions. The protocol used for the graded exercise test (GXT) consisted of a two

minute warm up at a speed of 1.2 mph and 0% grade. After the warm up, the actual data collection for the GXT began. The treadmill speed was increased to 3.0 mph at 0% grade. After the first stage, the grade was increased by 1% every minute thereafter while speed remained constant throughout the entire test. Heart rate and ratings of perceived exertion measurements were recorded every minute during the test, and blood pressure was recorded every two minutes. On completion of the test, heart rates and blood pressures were taken immediately post. Heart rates were taken every minute during the seven minute recovery and blood pressures were taken every other minute. Volume of oxygen uptake was assessed by the use of a metabolic cart (Sensor Medics 2900, Seattle, WA.). Subjects wore a head gear and a mouth piece that routed expired air through the metabolic cart. Precision gases were used to calibrate the metabolic cart before each testing session. Maximal oxygen uptake was determined if subjects met 2 out of the following 3 criteria: 1) $RER \geq 1.1$, 2) age predicted HR maximum, and 3) a leveling off in oxygen uptake.

During the evaluation of the tilt table test, each subject was placed in the supine position on a motorized tilt table and had 10 electrodes placed on the chest to monitor heart rate (HR). A blood pressure (BP) cuff was fitted around the upper arm for manual BP measurement. Heart rate and BP were measured during a 30-minute supine control period after 5, 10, 15, 20, 25, and 30 minutes. At the end of 30 minutes the tilt table was brought from a supine position to a 70° head-up position, taking approximately 15-20 seconds. The 30-minute tilt period began once the subject was in the 70° head-up position. The duration of the tilt test when tilting at 70° is recommended to last for at least 30 minutes according to Fitzpatrick et al. (1991). A HR rhythm strip was recorded every minute during the first 6 seconds of each minute. Blood pressure was recorded 30 seconds after the beginning of the 30-minute tilt and at every minute thereafter until

the end of the tilt period. Each subject was supported by straps that wrapped around the hips and chest (under the arms). The subject was asked to refrain from using the legs to support body weight. The subjects remained in this position for 30 minutes. The tilt test was discontinued if any of the following symptoms occurred: 1) presyncopal symptoms such as a fall in systolic BP greater than 20 mmHg between adjacent 1 minute measurements and/or sudden slowing of heart rate greater than 15 beats·min; 2) systolic BP fell below 80 mmHg; or 3) the subject requested to stop due to dizziness, nausea, or discomfort (Sather, Goldwater, Montgomery, & Convertino, 1986).

Following completion or discontinuance of the tilt portion of the test, the subject was placed back in the supine position in approximately 15-20 seconds. A 15-minute recovery period began upon reaching the supine position. Measurements (HR and BP) were made along the same time schedule as during the initial resting period. During the entire test, the subject was asked to refrain from unnecessary movement and conversation, aside from answering any questions from the investigators regarding his or her status. Temperature during the test was maintained at 23-24°C.

Muscle mass, fat mass, and bone mass of the body was assessed noninvasively using a Dual-Energy X-ray Absorptiometer (DEXA). Dual energy X-ray absorptiometry was determined using a Lunar™ QDR system according to the specifications of Lohman (1996). Transverse scans of the subject's whole body were made in the anteroposterior position. Scans were made in 0.6 to 1.0 cm intervals over the area being scanned. Standard error for this method of measuring body composition ranges from 2.5% to 3.5%. This procedure took approximately 30 minutes.

One repetition maximum (1RM) leg strength was assessed using the Cybex™ leg press machine. Upper body strength was assessed with the Cybex™ bench press machine. Subjects began by warming up with 4-5 submaximal repetitions. The resistance on any subsequent single lift was increased by 5-10 pounds according to the difficulty by which the subject executed the previous lift; a one-minute rest was allowed between trials. The 1RM was considered to be the maximum amount of weight that could be lifted through the subject's full range-of-motion. The 1RM testing was repeated 48 hours later to try and eliminate any learning effects that may have occurred.

Following the preliminary evaluation, the subjects began the training phase of the study. The subjects were assigned to a control or resistance training group. Subjects assigned to the control group were asked not to change their lifestyle (e.g., diet and exercise) over the 12 weeks of the study. The subjects assigned to the resistance training group participated in 12 weeks of resistance training twice a week. Training consisted of three sets of 10 to 12 repetitions for the first 4 weeks. After 4 weeks the repetitions were reduced from 12 to 8, thereby increasing the intensity. The resistance-training group trained using Cybex™ resistance machines. The subjects trained on 12 resistance machines (leg press, calf raise, leg curl, leg extension, bench press, pull-down, overhead press, seated row, abdominal, lumbar back, biceps, and triceps) designed to exercise the major muscle groups of the body. When 12 repetitions were achieved on all three sets, resistance was increased. Following the completion of the 12-week training period, both the control and resistance training groups completed all tests that were performed at the beginning of the study.

Design and Analysis

One-way Analyses of Variance (ANOVA) was used to analyze descriptive data of age, height, weight, and body composition between the resistance training group and the control group. Two-way ANOVAs were used to evaluate the dependent measures of body composition, strength, and $\dot{V}O_{2\max}$ between the two groups after training and the control period. Heart rates and blood pressures during the tilt test were analyzed using a 2 X 2 X 8 (test X group X time) repeated measures ANOVA. Location of significant differences were accomplished using the Tukey Multiple Comparison Test. Statistical significance was accepted at $p \leq 0.05$.

CHAPTER 4

RESULTS AND DISCUSSION

This study was completed over a period of 18 weeks that consisted of approximately 3 weeks of testing before and after the 12-week training period. The purpose of this study was to determine the physiological effects of a total body resistance training program on cardiovascular responses to an orthostatic challenge. The hypothesis for this study was that resistance training would improve heart rate and blood pressure responses to 70° head-up tilt in orthostatically intolerant elderly individuals. This chapter will discuss the results of both the control and resistance training group to the testing and training.

Subjects

Initially there were 18 subjects, 3 males and 15 females recruited for the study. Of the 18 subjects there were two males and 11 females (N = 13) who completed the study. Three subjects had a positive stress test and were not allowed to participate in the study. One subject did not complete the study because she fractured her foot during an activity outside of the study. Finally, another subject did not start the study due to severe osteoporosis. Therefore, 13 subjects were not randomly assigned to either the resistance training (RES=7) or the control (CON=6) group. The CON group was made up of 6 female subjects who could not attend training sessions due to time constraints. The RES group consisted of 5 females and 2 males. Subject characteristics for the 13 subjects are presented by group in Table 1. The two groups were similar ($p > 0.05$) with respect to age, percent body fat, and lean mass. In contrast, the control group was shorter, weighed less, and had lower BMI values than the RES group.

Table 1. SUBJECT CHARACTERISTICS (N=13)

	CON (N=6)	RES (N=7)
Age (yrs)	71 ± 6	66 ± 5
Height (cm)	163.1 ± 6.1	172.0 ± 5.8*
Weight (kg)	61.7 ± 9.4	82.5 ± 12.4*
BMI (kg)	23.3 ± 2.6	27.9 ± 4.2*
% Body Fat ^a	33.5 ± 9.0	35.5 ± 12.7
Lean Mass ^a (kg)	38.1 ± 2.4	50.5 ± 12.9

Values are means ± SD.

^a Determined from Dual Energy X- ray Absorptiometry (DEXA).

BMI: Body Mass Index=body weight (kg)/height in meters squared.

* $p \leq 0.05$ indicates significant difference between groups.

Strength Measurements

The training intensity for this particular study was low to moderate. This intensity level is probably part of the reason for the high adherence level (100%) and for the fact that none of the subjects were injured during the entire 12-week training period. The training intensity levels are shown in Table 2.

Both upper and lower body strength measurements were obtained from the appropriate 1RM and were taken at the beginning, at 4 weeks, at 8 weeks, and at the end of the study. The initial training percentages, expressed as a percentage of the 1RM, for the chest press (CP) were approximately 24% and progressed over the 12 weeks to approximately 57% of the initial 1RM for the upper body. The initial training percentages, expressed as a percentage of the 1RM, for the leg extension (LE) were lower than for the upper body, 22% and progressed over the 12-week training period to 52% of the initial 1RM for the lower body. The training intensities may have been low to moderate based upon feedback gained from several of the RES group members. When subjects came to train on Tuesday, they felt as if they had to readapt to the exercise because of the long period from Thursday to Tuesday of not training. The time off they experienced may have been detrimental to their abilities to increase weight significantly on Tuesdays.

Table 2. RESISTANCE TRAINING INTENSITIES OVER 12 WEEKS FOR THE RESISTANCE (RES) GROUP (N=7).

		Weeks 0-4	Weeks 5-8	Weeks 9-12
Upper Body	Current training %	24.0%	39.0%	52.0%
	% of initial 1RM	24.0%	40.0%	57.0%
Lower Body	Current training %	22.0%	37.4%	43.0%
	% of initial 1RM	22.0%	39.7%	52.0%

All values are presented as percentages of each person's cumulative 1RM results. (Upper Body: 49 ± 27 kg, 51 ± 20 kg, 56 ± 30 kg; Lower Body: 65.3 ± 29 kg, 76 ± 21 kg, 80 ± 31 kg).

All strength measurements are presented in Table 3. After the 12-week control period, the CON group had no significant differences ($p > 0.05$) in chest press strength (29 ± 7 to 29 ± 6 kg) as was expected. The chest press measures were further evaluated by dividing chest press by the appropriate pre or posttest body weight. The CON group had no changes in chest press strength in relation to body weight. As anticipated, no significant differences ($p > 0.05$) were found in pre to posttest values for the CON group in leg strength. Similar to the chest press, the leg extension measures were further evaluated by dividing leg extension by the appropriate pre or posttest body weight. There were no significant differences found in either pre to posttest values for the CON group in leg strength in relation to body weight.

Table 3. STRENGTH MEASUREMENTS PRE AND POST 12 WEEKS OF TRAINING (N=13).

	CON (N=6)		RES (N=7)	
	Pre	Post	Pre	Post
CP (kg)	29 ± 7	29 ± 6	46 ± 24	55 ± 29* [§]
CP/BW(kg)	.50 ± .14	.48 ± .12	.56 ± .26	.67 ± .31* [§]
LE (kg)	53 ± 12	58 ± 10	62 ± 20	80 ± 31 ^{§‡}
LE/BW (kg)	.91 ± .15	.97 ± .17	.77 ± .30	.98 ± .37 ^{§†}

Values are means ± SD.

CP= Chest Press; BW= Body Weight; LE= Leg Extension.

CP/BW- Chest Press divided by the appropriate body weight pre and post.

LE/BW= Leg Extension divided by the appropriate body weight pre and post.

* $p \leq 0.05$, indicates significant difference between groups.

[§] $p \leq 0.05$, indicates significant difference between pre and posttest.

[‡] $p = 0.08$, indicates significant difference between groups.

[†] $p = 0.07$, indicates significant difference between groups.

Following the 12-weeks of resistance training, the RES group had significant increases ($p \leq 0.05$) in chest press strength from 46 ± 24 kg to 55 ± 29 kg, a 20% increase. When dividing chest press by the appropriate body weight, significant increases ($p \leq 0.05$) were found in upper body strength per unit mass (19.6%). Lower body strength increased (62 ± 20 kg to 80 ± 31 kg) by 29% between pre and posttesting. When the lower body strength results were further evaluated by dividing the leg extension weight by the appropriate pre or posttest body weight, significant increases were also ($p \leq 0.05$) found between pre and posttraining. When comparing the CON and RES groups, there were significant differences in chest press strength for the RES group for both absolute and relative strength gains. However, when lower body strength gains for the CON and RES groups were compared, the two groups did not quite reach significance for leg extension strength ($p = 0.08$) or for relative strength gains ($p = 0.07$). The reason for leg strength not to be different between the two groups could be due to the variability associated with the RES group. These increases in upper and lower body strength are similar to those presented in other studies. Tatro et al. (1992) found upper body strength to increase by 26% and lower body strength to increase by 20% after 19 weeks of resistance training on young adults. After 6 months of resistance training on elderly individuals, Carroll et al. (1994) found strength gains for the upper body to be approximately 26% and the lower body increased strength by approximately 22%.

Body Composition

In studies with a duration of 12 weeks or less, differences in body composition may or may not be found. The dual-energy X-ray absorptiometry machine was used in this study to determine differences in percent body fat, bone density, and lean mass.

All scans were performed using the whole-body scan mode. Table 4 presents results obtained from the DEXA body composition analyses. Body weight and bone density did not change in either group from pre to posttesting. The fact that significant changes in bone density were not found is consistent with a study by Layne and Nelson (1999) who indicated that a minimum of six months is required to increase bone density following a resistance training program. There was a significant 4.4% increase (50.5 ± 12.9 to 52.7 ± 13.1 kg) in total lean mass for the RES group found for pre to posttest values. Because body weight was maintained for the RES group (82.5 ± 12.4 to 82.5 ± 12.8 kg) and lean mass increased, fat mass must have decreased. However, the decrease in percent body fat was not statistically significant (35.5 ± 12.7 to $34.2 \pm 14.8\%$). These results are similar to what McCarthy et al. (1997) found using DEXA for determining body composition. McCarthy et al. reported lean body mass to increase by 3.4% during their 12-week resistance training program in which subjects trained three days per week. There were also no significant changes in body weight for the resistance training group used by McCarthy et al.

Table 4. BODY COMPOSITION^a PRE AND POST 12 WEEKS OF RESISTANCE TRAINING (N=13)

	CON (N=6)		RES (N=7)	
	Pre	Post	Pre	Post
BW (kg)	61.7 ± 9.4	61.0 ± 8.7	82.5 ± 12.4	82.5 ± 12.8
BMI (kg)	23.3 ± 2.6	23.1 ± 2.5	27.9 ± 4.2	28.0 ± 4.3
% Body Fat	33.5 ± 9.0	33.5 ± 8.9	35.5 ± 12.7	34.2 ± 14.8
Bone Density ^a (g/cm ²)	1.020 ± .099	1.021 ± .087	1.181 ± .118	1.198 ± .112
Lean Mass ^a (kg)	38.1 ± 2.4	39.1 ± 2.1	50.5 ± 12.9	52.7 ± 13.1 [§]

Values are means ± S.D.

^a Determined from DEXA.

BW=Body Weight

BMI: Body Mass Index=body weight (kg)/height in meters squared.

[§]p≤0.05, indicates significant difference between pre and posttest.

Cardiovascular Measurements

There were no differences in any cardiovascular measurements between groups or pre- to posttest values. All cardiovascular measurement results are shown in Table 5. Maximal oxygen uptake levels increased approximately 4% and treadmill times increased approximately 8% but these changes were not statistically significant from pre to posttesting for the RES group. Maximal oxygen uptake and treadmill times for the CON group also did not change significantly from pre to posttesting (less than 2%). This is consistent with a study by Lightfoot et al. (1994) who found similar results in cardiovascular measurements for the $\dot{V}O_{2\max}$ test. The protocol used by Lightfoot et al. was not presented in the methods of their study, nonetheless, no significant changes pre to posttraining between groups were found in $\dot{V}O_{2\max}$ or heart rate maximum responses for the two groups tested. Because resistance exercise training is not considered aerobic, the results from the $\dot{V}O_{2\max}$ test were to be expected

Table 5. MEASUREMENTS FROM GRADED EXERCISE TEST PRE AND POST 12 WEEKS OF RESISTANCE TRAINING.

	CON (N=6)		RES (N=7)	
	Pre	Post	Pre	Post
VO _{2max} (ml·kg ⁻¹ ·min ⁻¹)	22.7 ± 5.3	23.0 ± 7.1	22.9 ± 6.7	23.8 ± 8.0
Treadmill Time (min)	12.1 ± 4.3	12.2 ± 5.0	11.6 ± 5.2	12.5 ± 7.0
Max HR (bpm)	135 ± 21	138 ± 15	147 ± 11	150 ± 17
Max RPE	18 ± 2	17 ± 2	17 ± 2	18 ± 2
Max SBP (mmHg)	200 ± 14	194 ± 28	201 ± 10	202 ± 23
Max DBP (mmHg)	90 ± 15	86 ± 15	93 ± 7	91 ± 15

Values are means ± S.D.

VO_{2max}: Maximal oxygen uptake test.

Max HR: Maximum Heart Rate during VO_{2max} test.

Max RPE: Maximum Rating of Perceived Exertion during VO_{2max} test.

Max SBP: Maximum Systolic Blood Pressure during VO_{2max} test.

Max DBP: Maximum Diastolic Blood Pressure during VO_{2max} test.

Tilt Testing

Of the 13 subjects in the study, only 9 subjects completed the 30-minute tilt pretest and posttest. Of the four subjects who did not complete the pre- and posttesting, one subject was in the CON group and three were in the RES group. The CON subject complained of dizziness during both the pre and posttesting tilt periods. Tilt was stopped at minute 22 for the pretest and at minute 25 for the posttest (Appendix C).

The following three RES group subjects will be described as subject A, B, and C. Subject A from the RES group did not complete the pretilt test. Subject A experienced feelings of dizziness and an increase in body temperature during the tilt; therefore, the tilt test was stopped at minute 22 during the pretest. After the 12-week resistance training program, Subject A had no presyncopal symptoms throughout the post tilt test (Appendix D). Interestingly, Subject B from the RES group experienced no presyncopal symptoms during the pretilt test. Conversely during the posttilt test, Subject B had symptoms of dizziness and lightheadedness and the tilt was discontinued at minute 22 (Appendix E). Subject C had similar results as Subject B. Subject C also had no problems during the pretilt test, but did experience presyncopal symptoms of lightheadedness during the posttilt test and tilt was stopped at minute 24 (Appendix F).

It is not clear why these 4 subjects did not complete tilt testing either pre or posttesting and the other subjects did. Resistance exercise training does not seem to influence tilt tolerance since the two subjects that experienced presyncopal symptoms in the posttilt test following the resistance training intervention had no signs of intolerance during pretesting. The fact that resistance training does not prove advantageous during an orthostatic stress is consistent with a study by Ludwig and Convertino (1994) who measured physical versus physiological variables

associated with various theories of orthostatic intolerance to test the hypothesis that physical factors rather than physiological reflex mechanisms were dominant in contributing to orthostatic tolerance. Ludwig and Convertino found that although low tolerance to an orthostatic stress has been highly correlated to high leg compliance, it seems that orthostatic tolerance is not heavily influenced by venous compliance of the lower extremities. To conclude, Ludwig and Convertino suggested that while orthostatic intolerance may be dependent upon a variety of physiological reflexes, physical factors such as height and blood volume tend to dominate the prediction of time to syncopal symptoms during lower body negative pressure. However, Ludwig and Convertino used the LBNP test and it is possible that variables important to the prediction of tolerance for progressive LBNP are different than those predicting tolerance or cardiovascular changes for the tilt or stand tests. The choice of test for orthostatic intolerance or challenge should depend on which systems are to be tested and the objectives of the study.

In considering physical characteristics of the individuals who did not make it through the 30-minute tilt test, the four subjects tended to have higher body weights (80.9 ± 19.1 kg) than those subject who did make it through the tilt test (69.5 ± 12.7 kg). However, one subject in this group was at the lower end of body weight range at 54 kg. Percent body fat also tended to be higher in the subjects who experienced syncopal symptoms ($40.5 \pm 7.6\%$) than those who did not experience any symptoms ($32.1 \pm 11.8\%$). There was not much of a difference in height between the subjects who had syncopal symptoms and those who did not. An increase in blood volume as a result of resistance training was not taken into account to determine if this could help orthostatic tolerance. Researchers have found that increased blood volume may aid in the ability to tolerate an orthostatic stress (Ludwig & Convertino, 1994). In contrast, researchers

have found that an increase in blood volume due to resistance training does occur, but does not improve orthostatic tolerance (McCarthy et al., 1997).

Physical characteristics may or may not have played a role in the determination of orthostatic intolerance in these four individuals and perhaps they did not. Nevertheless research has indicated that both physical and physiological factors contribute to the resulting blood pressure response to an orthostatic stress. Further research needs to be conducted on the physical versus the physiological factors that may contribute to an elderly individuals ability to tolerate an orthostatic stress.

Data on subject characteristics, strength, body composition, and cardiovascular measurements for the subjects who completed tilt testing are presented in Appendix G. To analyze the tilt data for the subjects who made it through the 30-minute tilt test, heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were analyzed for each five-minute interval (minutes 1-5, 6-10, 11-15, 16-20, 21-25, and 26-30) during the tilt. Therefore six, five-minute intervals were studied to identify significance between resting, the 6 intervals of the tilt period, and recovery mean values.

Due to the small sample size and large variability among subjects, no significant differences between CON and RES groups were found for HR, SBP, DBP, and MAP after the 12 weeks of training (Figure 1-8). There were however, some differences between pre and post measurements of HR, SBP, DBP, and MAP for the two groups.

The CON group had a significant increase in HR going from rest to a 70° tilt. The CON group also had significant decreases in HR from tilt to recovery (Figure 1). Systolic blood pressure was maintained across tilt in both pre and posttesting (Figure 2). Diastolic blood pressure was maintained across tilt for pretesting. However, during the recovery DBP increased

significantly compared to rest (Figure 3). During the posttest, DBP was significantly higher after the first 5 minutes of the tilt until the end of the tilt test where DBP returned to resting values (Figure 3). This increase in DBP during the posttest may indicate that there was a slight increase in total peripheral resistance to help maintain MAP. Mean arterial pressure was maintained throughout tilt for both pre and posttesting in the CON group (Figure 4).

During the pretesting measurements of the tilt test for the RES group, HR increased through the tilt period, although not significantly, and then decreased during the recovery period (Figure 5). Due to the small sample size and the variability associated with the HR, no differences were found. When posttesting tilt measurements were taken, there were significant increases in HR from rest to tilt and tilt to recovery. When evaluating the HR response from pre to posttests, HR had a trend to be higher during the tilt at minutes 1-5 ($p=0.08$), at minutes 11-15 ($p=0.09$), and at minutes 21-25 ($p=0.01$)

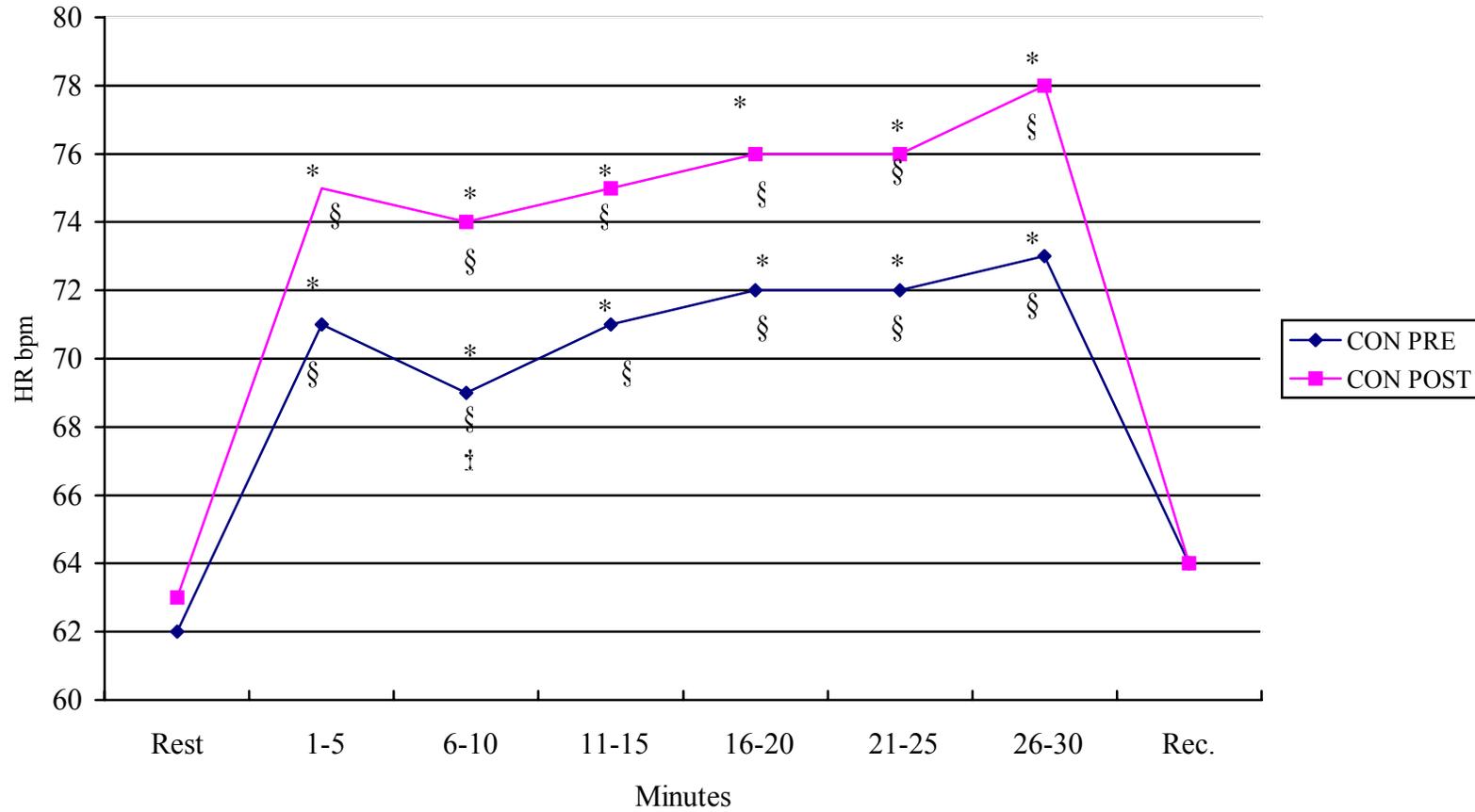


Figure 1. PRESENTS HEART RATE FOR PRE AND POST TILT TESTS FOR THE CONTROL GROUP.

* $p \leq 0.05$, indicates significant difference from rest HR.
 § $p \leq 0.05$, indicates significant difference from recovery HR.
 ‡ $p \leq 0.05$, indicates significant difference from HR (26-30).

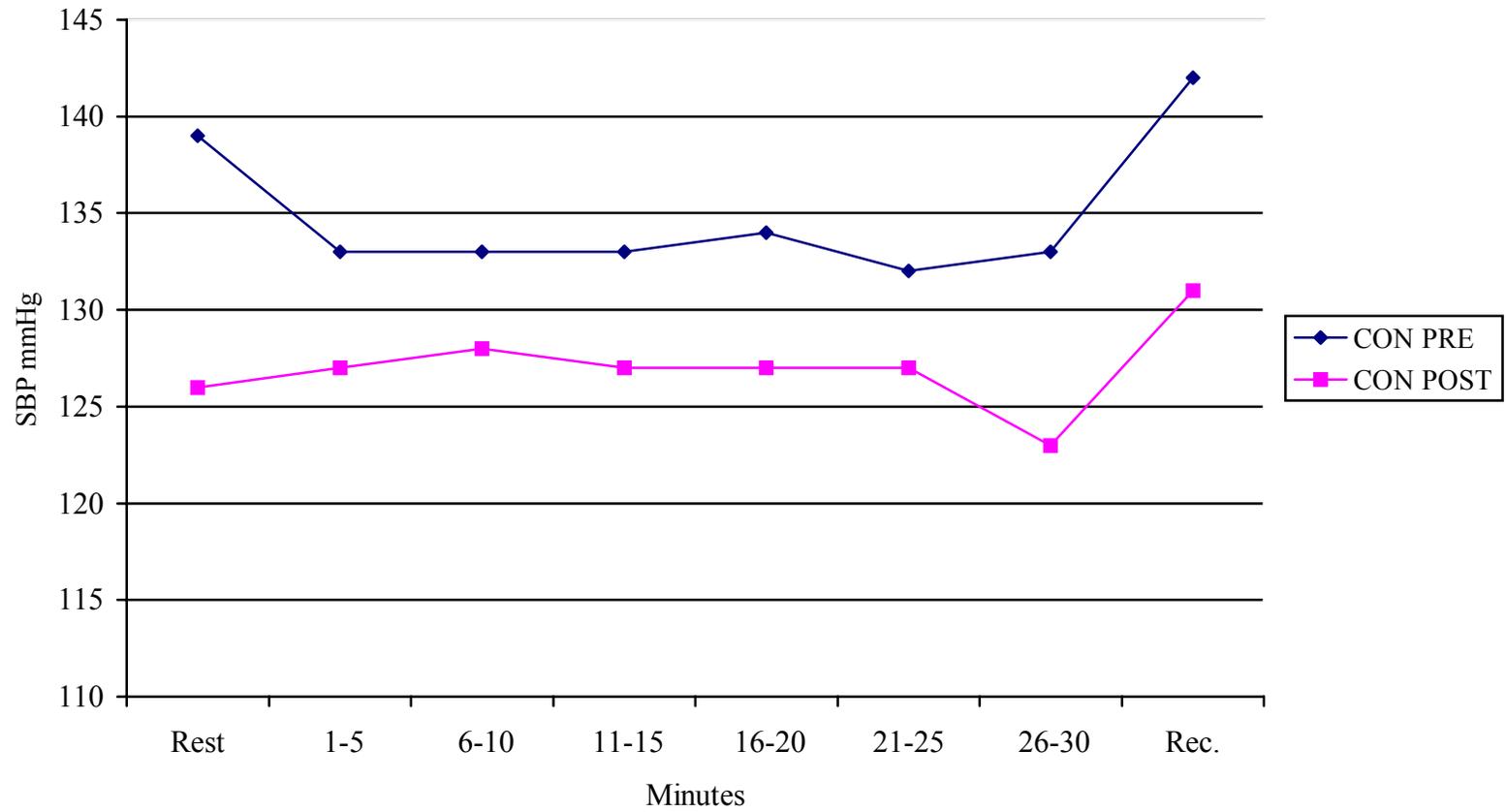


Figure 2. PRESENTS SYSTOLIC BLOOD PRESSURE FOR PRE AND POST TILT TESTS FOR THE CONTROL GROUP.

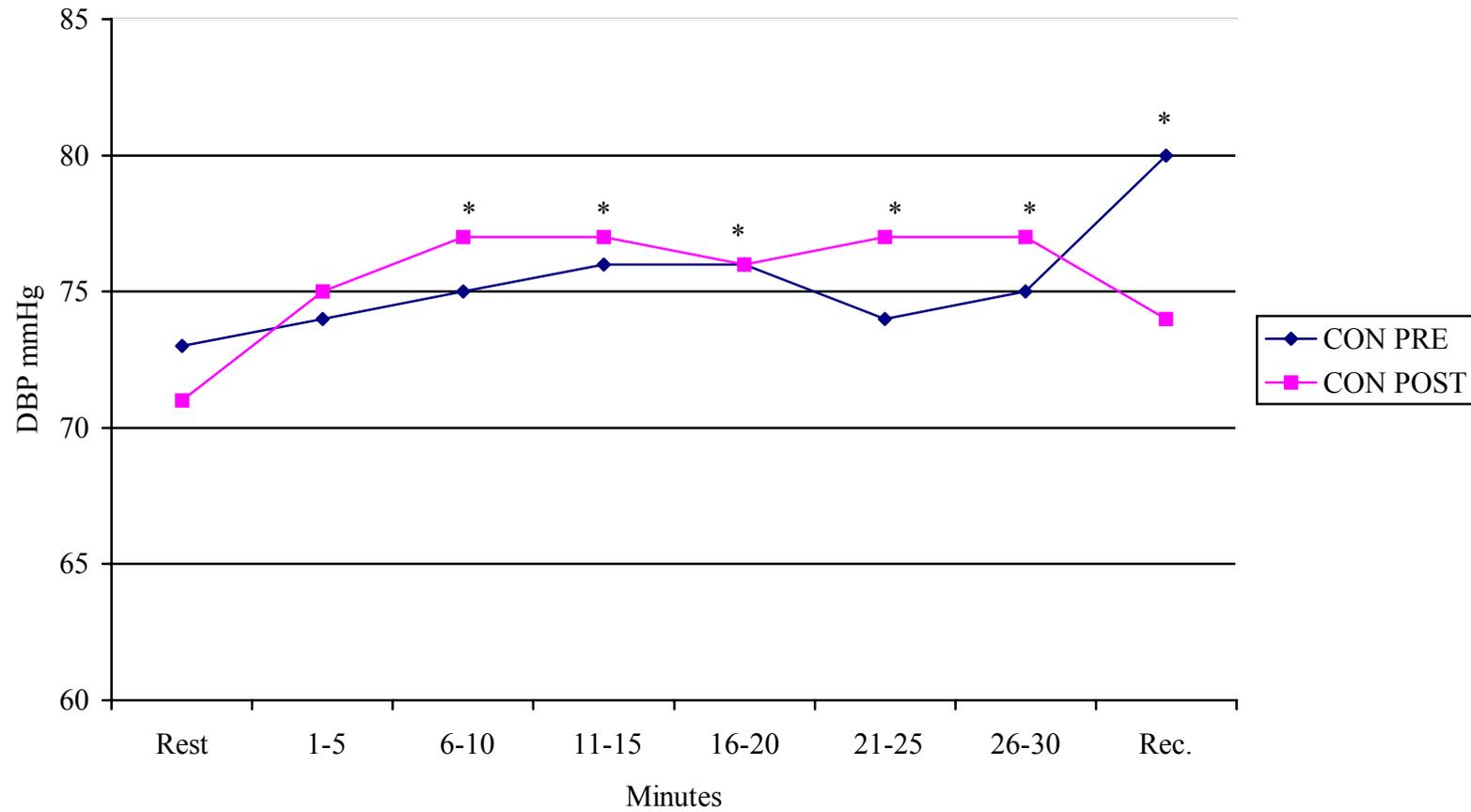


Figure 3. PRESENTS DIASTOLIC BLOOD PRESSURE FOR PRE AND POST TILT TESTS FOR THE CONTROL GROUP. * $p \leq 0.05$, indicates significant difference from Rest DBP.

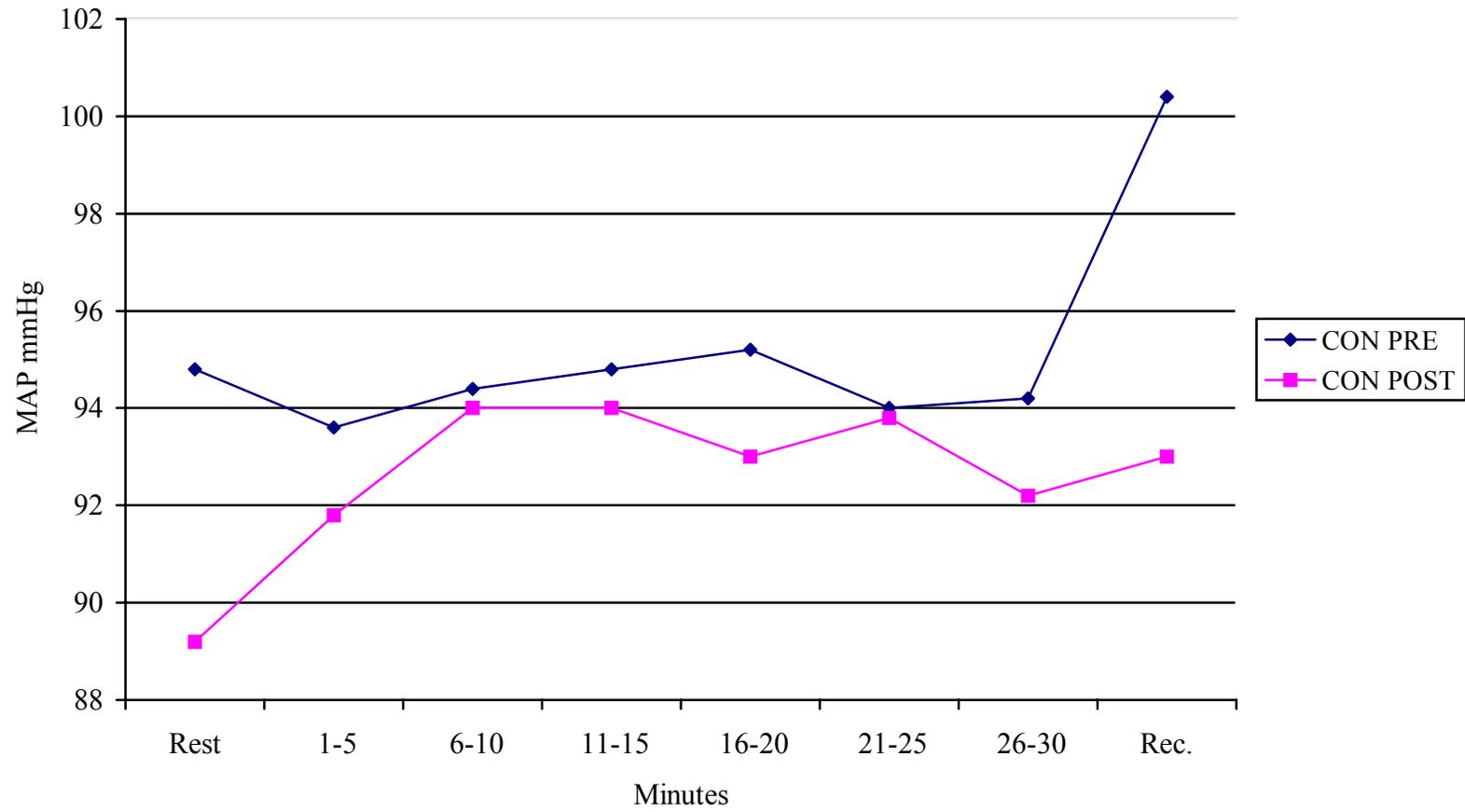


Figure 4. PRESENTS MEAN ARTERIAL PRESSURE FOR PRE AND POST TILT TESTS FOR THE CONTROL GROUP.

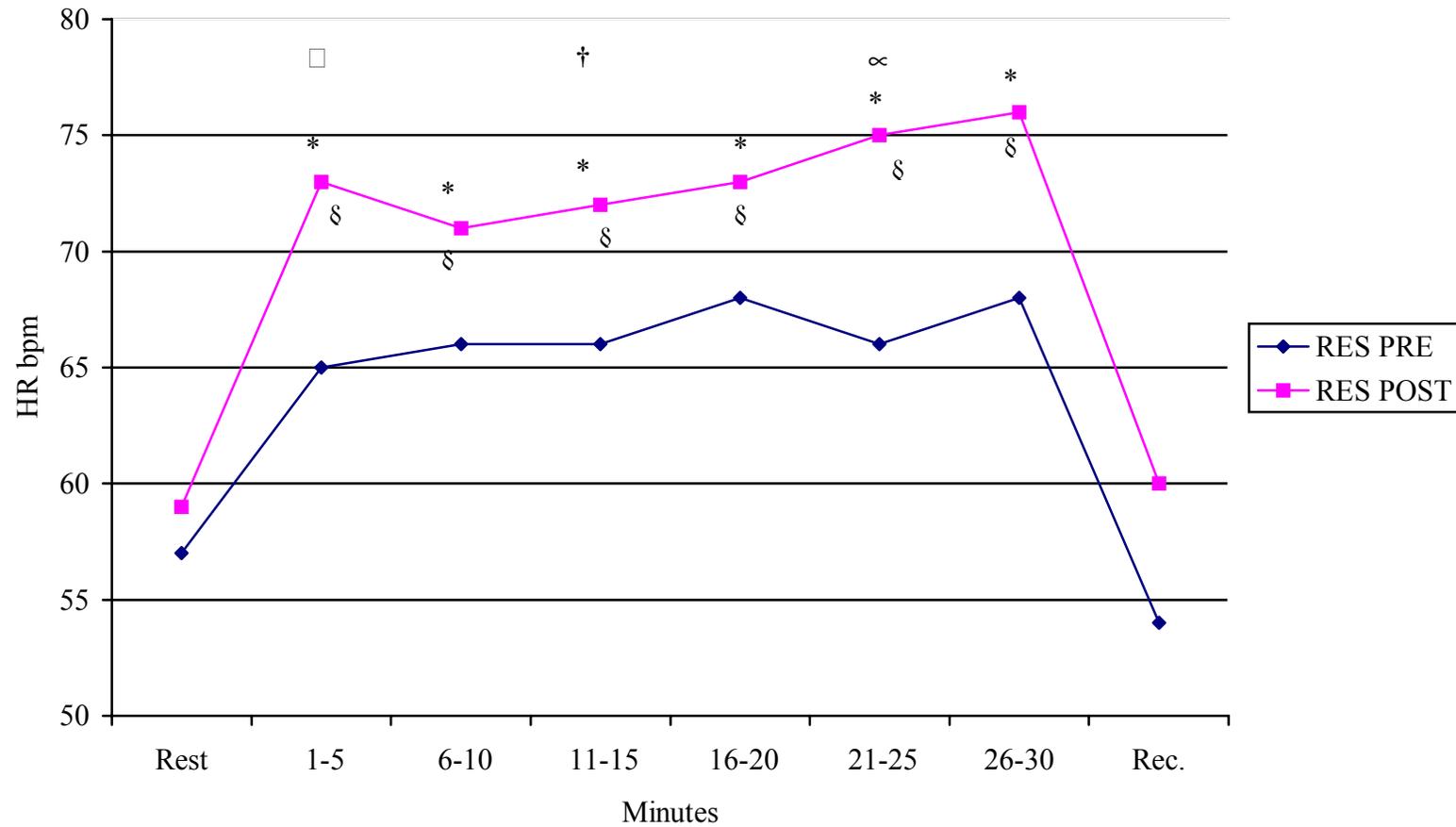


Figure 5. PRESENTS HEART RATE FOR PRE AND POST TILT TESTS FOR THE RESISTANCE GROUP.

* $p \leq 0.05$, indicates significant difference from Rest HR.

§ $p \leq 0.05$, indicates significant difference from Rec. HR.

□ $p = 0.08$, indicates significant difference between pre and post tests.

† $p = 0.09$, indicates significant difference between pre and post tests.

∞ $p = 0.01$, indicates significant difference between pre and post tests.

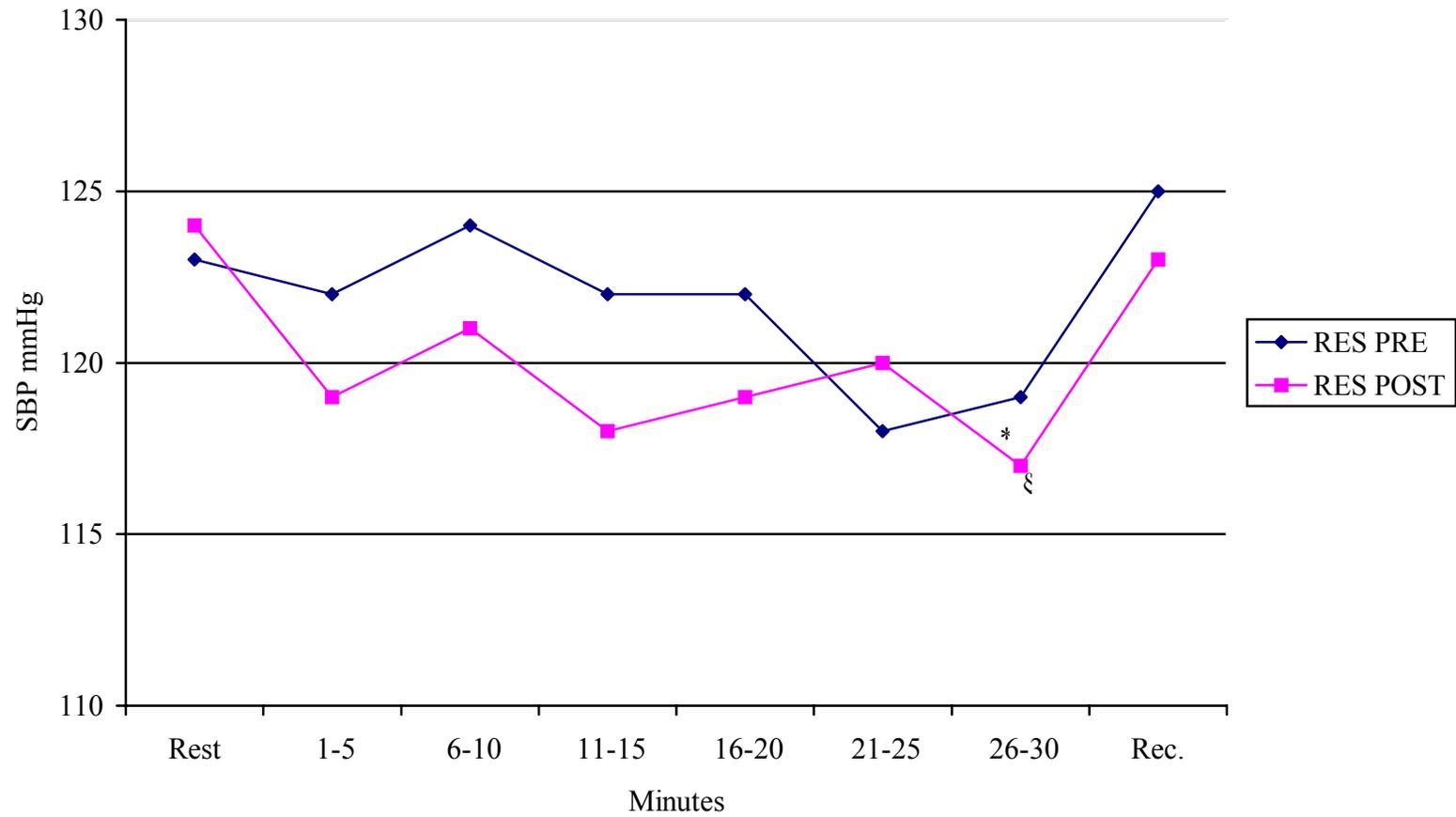


Figure 6. PRESENTS SYSTOLIC BLOOD PRESSURE FOR PRE AND POST TILT TESTS FOR THE RESISTANCE GROUP.

* $p \leq 0.05$, indicates significant difference from Rest SBP.

§ $p \leq 0.05$, indicates significant difference from Rec. SBP.

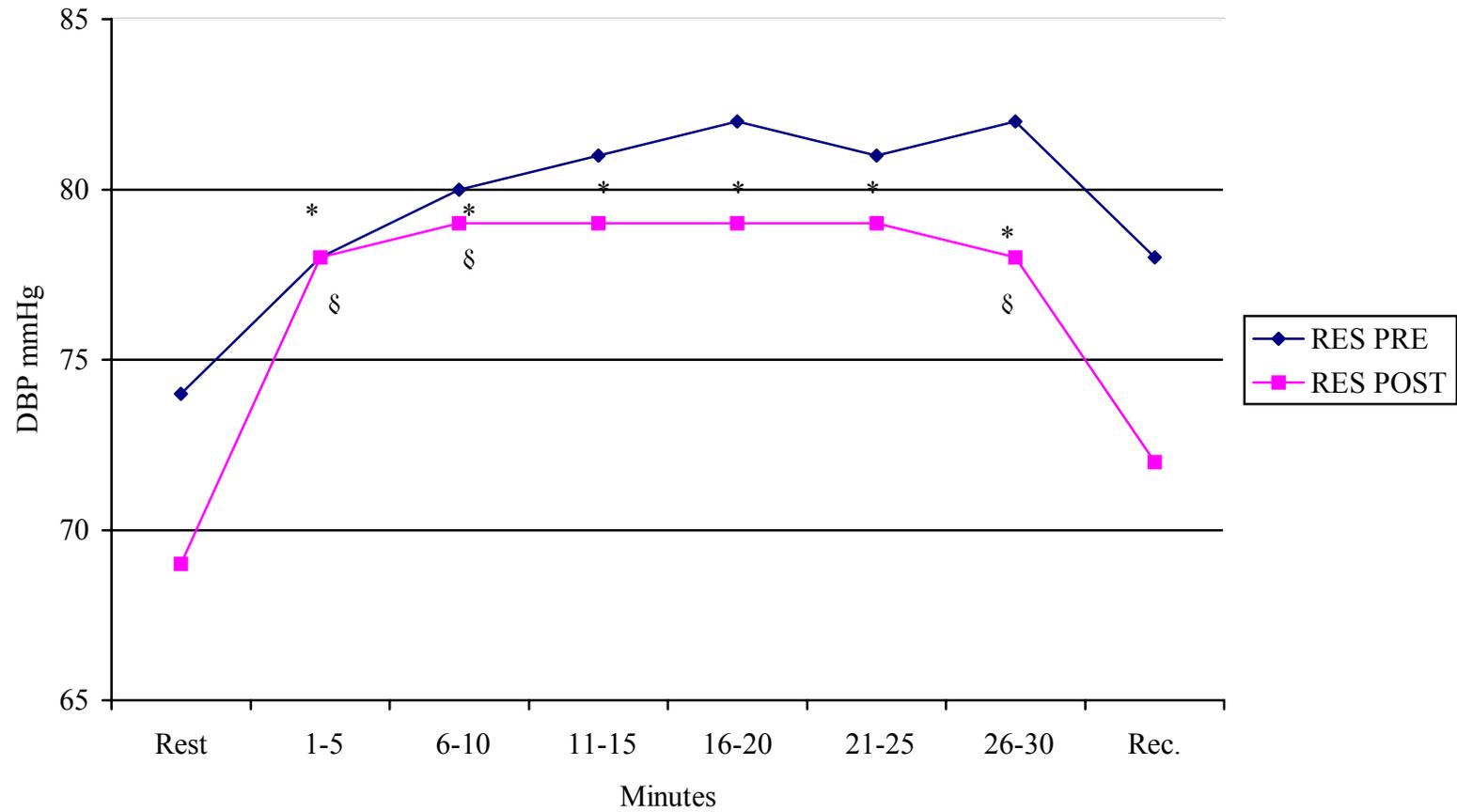


Figure 7. PRESENTS DIASTOLIC BLOOD PRESSURE FOR PRE AND POST TILT TESTS FOR THE RESISTANCE GROUP.
 * $p \leq 0.05$, indicates significant difference from Rest DBP.
 § $p \leq 0.05$, indicates significant difference from Rec. DBP.

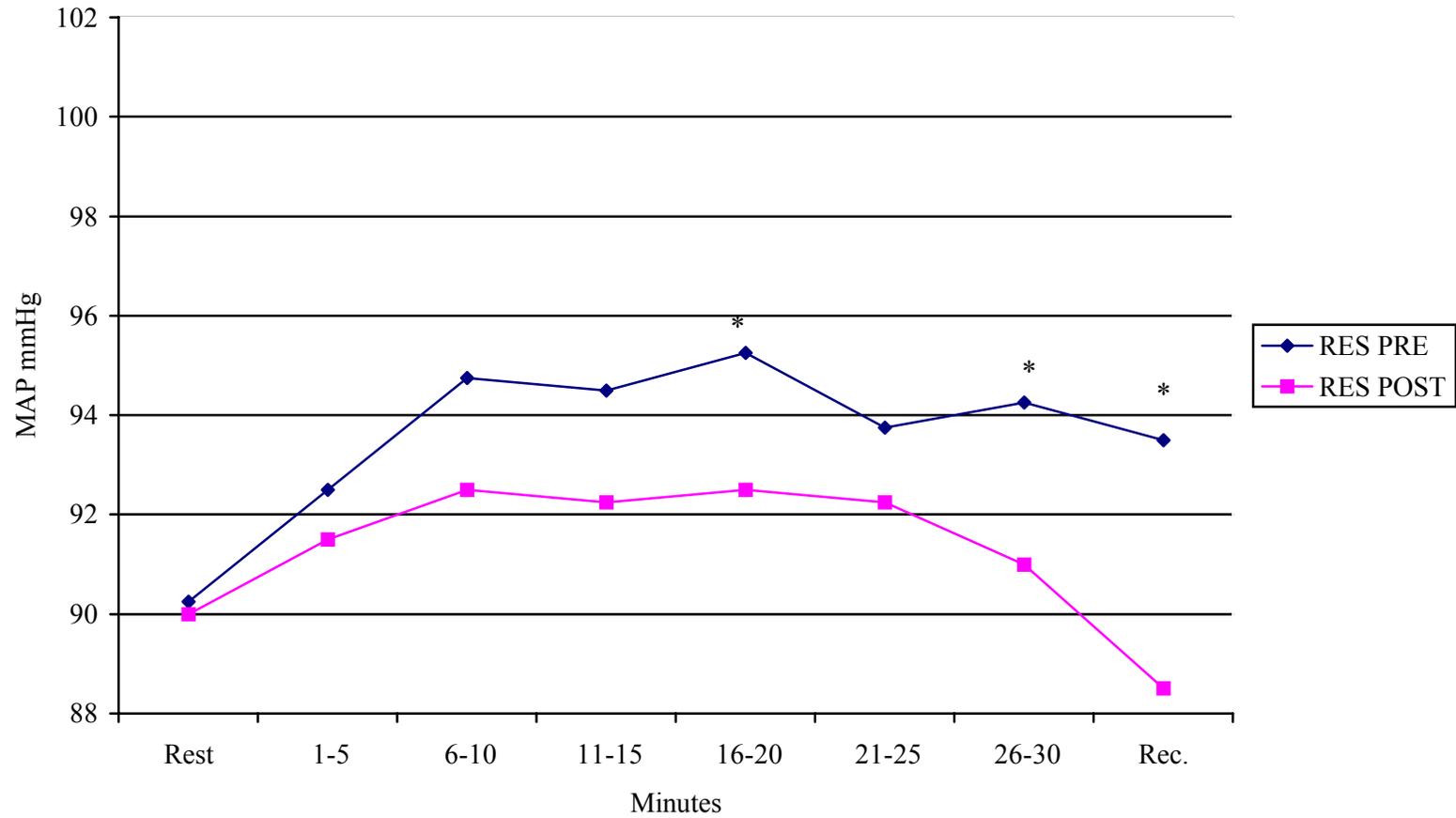


Figure 8. PRESENTS MEAN ARTERIAL PRESSURE FOR PRE AND POST TILT TESTS FOR THE RESISTANCE GROUP.
 * $p \leq 0.05$, indicates significant difference from Rest MAP.

compared to the pretest. The increase in HR response during the posttesting may be due to a greater reduction in stroke volume with tilting or a decrease in total peripheral resistance (TPR). However, it is unlikely that TPR changed since DBP increased significantly during the posttest tilt and the posttest tilt DBP was not significantly different from pretesting DBP (Figure 7). This is consistent with previous research by Tatro et al. (1992) who found HR to increase over time during an orthostatic challenge. Tatro et al. found HR to be slightly higher after the resistance training period than before training which is similar to the findings in this study. Tatro et al. also found stroke volume and cardiac output to be lower after resistance training, resulting in an increased systemic resistance after training to help maintain MAP. However, Tatro et al. suggested that resistance exercise training did not influence the ability to tolerate orthostasis in young adults.

Systolic blood pressure was maintained during pre and posttest tilt tests for the RES group (Figure 6). Only during minutes 26-30 was there a significant decrease in SBP for pre and posttests. Mean arterial pressure was maintained through both pre and posttests (Figure 8). During the pretest MAP was higher than at rest for minutes 16-20, 26-30, and recovery. Due to the small sample size and variability, the significance of these findings may not be of physiological significance.

If HR and DBP are increasing after a resistance program, then perhaps training is not helping to facilitate venous return and more blood may be pooling and causing stroke volume to be decreased. This is in conflict with research that suggests resistance training decreases leg compliance and improves venous return in young adults (Lightfoot et al., 1994). Although calf compliance has been highly correlated with the ability to maintain blood pressure (Lightfoot et al.), Ludwig and Convertino (1994) found that orthostatic tolerance was not greatly influenced

by venous compliance of the lower extremities. More research is needed to determine the effects of resistance exercise training on elderly individuals who experience problems with orthostatic intolerance.

Studies have suggested that the reproducibility of head-up tilt testing both drug-free and with isoproterenol administration varies between 65% and 85% when repeat testing is conducted on the same day or substantially later (Foglia-Manzillo et al., 1999). Therefore, the reproducibility of tilt testing may be a factor in the cause of such variability in the subjects tested in this study. It may have been possible that the subjects tilt test results varied due to the low reproducibility.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Orthostatic intolerance is a problem that occurs in elderly individuals as a result of various physiological and possibly physical characteristic changes that occur with aging. The ability for a resistance exercise training program to positively affect orthostatic tolerance in elderly individuals could be an important nonpharmacological treatment for this condition. Therefore, the purpose of this study was to determine the effects of resistance training on the cardiovascular responses of elderly men and women during an orthostatic challenge. The orthostatic challenge used in this study to determine cardiovascular responses was a 70° head-up tilt test.

Thirteen volunteers from the Washington County area were recruited for this study and were placed into one of two groups, either a control (CON) or a resistance training (RES) group. The study's protocol required the subjects to participate in a series of tests prior to and after the 12-week training period. These tests included maximal oxygen uptake, cardiovascular responses to 30 minutes of 70° head-up tilt, body composition, and strength. The CON group subjects were asked not to change their normal lifestyles throughout the 12-week period, while the RES group subjects were asked to train twice a week using 12 different resistance exercise machines designed to exercise the entire body at an intensity level that progressed from 22% to 57% of the initial 1RM.

Conclusions

Although the training intensities for this study were low to moderate, significant strength gains were found for the RES group after the 12-weeks. Possibly as a result of the strength training, lean mass was found to increase for the RES group; however, body fat percent did not decrease significantly. This could be due to the small sample size used in the study. In addition, bone density and body weight had no significant changes between the two groups tested. As predicted, cardiovascular measurements in response to the VO_{2max} test did not change in either the CON or the RES group after the 12 weeks.

The tilt test data resulted in only 9 subjects being able to complete the 30-minute tilt period. Four subjects were not able to complete tilt testing due to the occurrence of syncopal symptoms such as dizziness or lightheadedness in which the tilt test was stopped. Resistance training did not seem to influence tilt tolerance in these individuals since two of the subjects made it through the pre tilt test without experiencing any symptoms, but when exposed to a 12-week resistance training program, the same two subjects experienced symptoms causing the tilt test to be discontinued. One other subject in the RES group did not make it through the pre tilt test, but made it through the post tilt test. Finally, one CON group subject did not make it through either pre or post tilt tests.

For the 9 subjects who did make it through the tilt test periods, the CON group maintained MAP throughout both the pre and post tilt tests. The RES group had significant increases in HR compared to pretest values. During the post tilt test DBP significantly increased indicating that perhaps training did not help facilitate venous return and, therefore, more blood pooled in the extremities causing stroke volume to decrease. This finding was unexpected due to the research that has shown improvements in orthostatic tolerance and cardiovascular responses

after resistance training (Lightfoot et al., 1994). Therefore, while the 12-week resistance training program significantly improved strength in both upper and lower body measurements, resistance training had no positive effects on the cardiovascular responses to tilt.

Recommendations for Future Research

The first recommendation would be to conduct more research on elderly individuals who suffer from symptoms of orthostatic intolerance. The mechanisms involved in determining orthostatic intolerance, whether physical or physiological are quite unclear and require further research. In addition, the correct method of testing orthostatic intolerance and cardiovascular responses (tilt, LBNP, or stand tests) should be investigated to ensure that accurate results are obtained when trying to detect changes in an orthostatic challenge after a training program. It is important for future research to involve a much larger sample size to help reduce the initial differences between the subject groups. Randomization techniques should also be considered to help normalize the subject groups and so that the results can be better accepted by the general population.

Recommendations for Future Research Involving the Tilt Test

Further research needs to be performed on the tilt test to determine whether this is a valuable tool for assessing changes in cardiovascular responses after an intervention program. Reproducibility of head-up tilt testing is still open to question because of the great variability in the methodology of different studies. Most studies suggest that reproducibility of head-up tilt testing both drug-free and with isoproterenol administration vary between 65% and 85% when repeat testing is conducted on the same day or substantially later (Foglia-Manzillo et al., 1999). Therefore, the reproducibility of tilt testing may be a factor in the cause of such variability in the

subjects tested in this study. In addition, tilt testing may be more suitable for diagnostic purposes rather than determining cardiovascular changes before and following a 12-week resistance training program.

It is also possible that the subject vascular resistance was not as high during the posttesting due to a learning effect, which may have caused the different cardiovascular responses during the posttilt test as opposed to the pretilt test. Therefore it is recommended to include familiarization testing on the tilt table with the subjects before pretesting tilt data is collected.

This study used a 70° tilt angle to test orthostatic intolerance, however, it has been suggested that tilt tests at angles of >60° would increase the number of false positive tests (Fitzpatrick, Theodorakis, Vardas, & Sutton, 1991). This indicates that possibly for future research a tilt angle of 60° or less would produce more accurate results and would decrease the chances of false positives. On the other hand, it has also been suggested that tilt angles <60° do not seem to provide enough of an orthostatic challenge and therefore result in a lower number of positive test responses (Benditt et al., 1996).

In question also is the use of isoproterenol infusion during tilt studies. Isoproterenol has been recommended and can possibly be a useful tool for eliciting susceptibility to orthostatic intolerance in certain individuals. Infusion of isoproterenol may facilitate recognition of susceptible subjects and, therefore, increase the reliability of the tilt test (Benditt et al., 1996).

Since there is no standard protocol for tilt testing, the duration of the tilt test when tilting at 70° should last for at least 30 minutes (Fitzpatrick et al., 1991). This is because we found subjects to become symptomatic in the final 5-10 minutes of the 30-minute tilt period. When the tilt duration is only 10-15 minutes, there is a higher incidence of false negative results. For the

reasons stated it is important in the future for researchers to have a tilt duration of at least 30 minutes to obtain the most accurate results.

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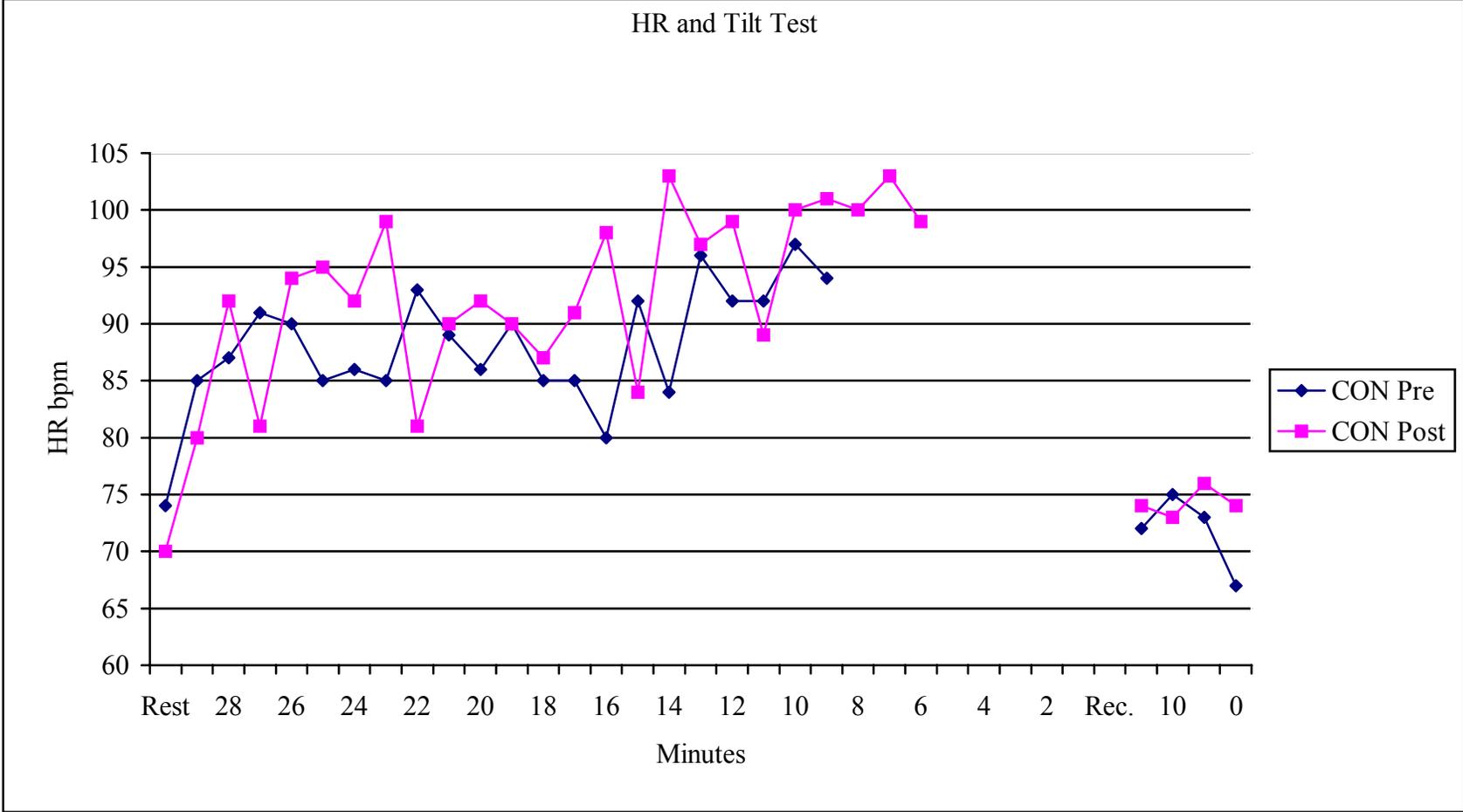
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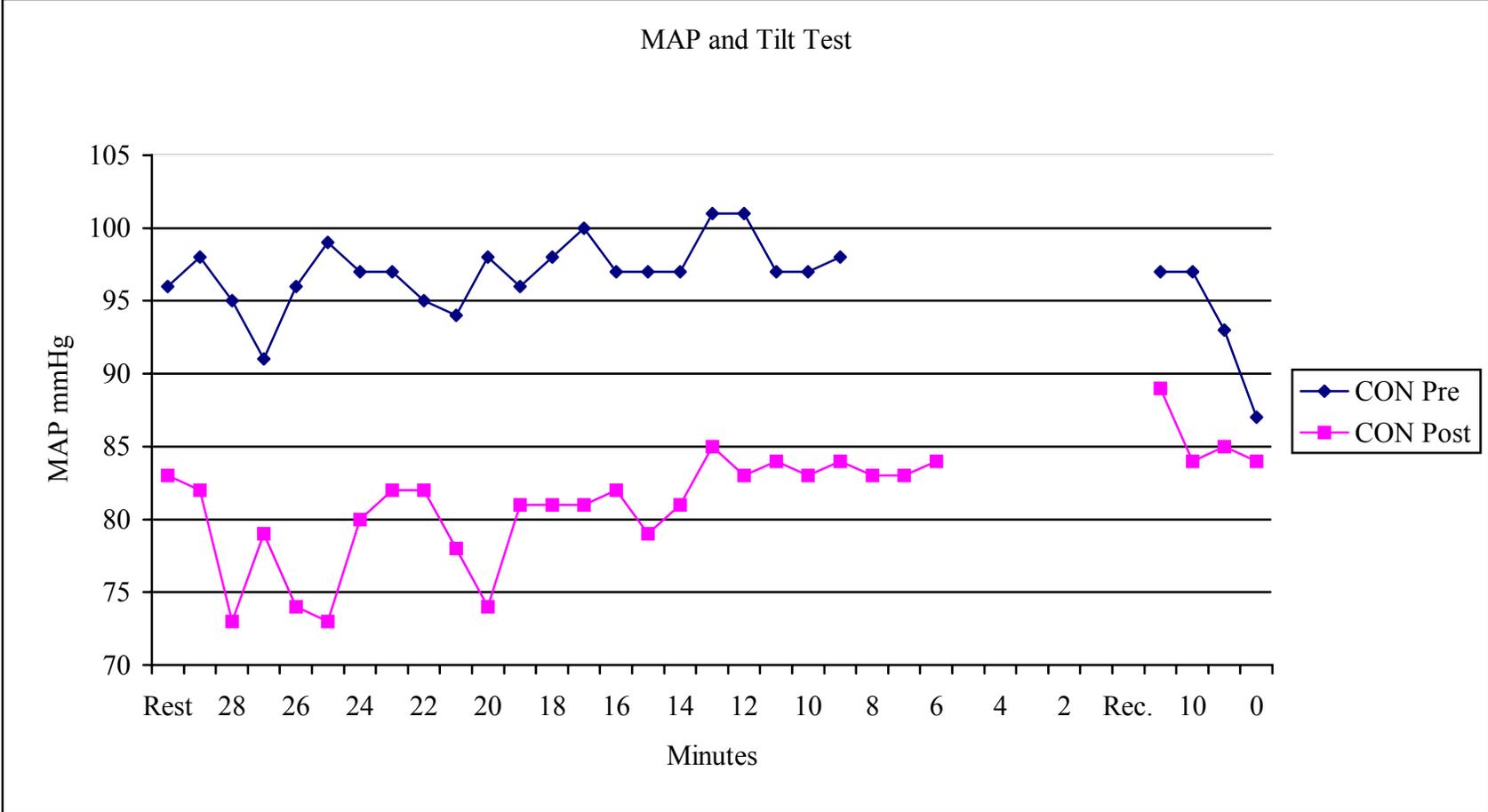
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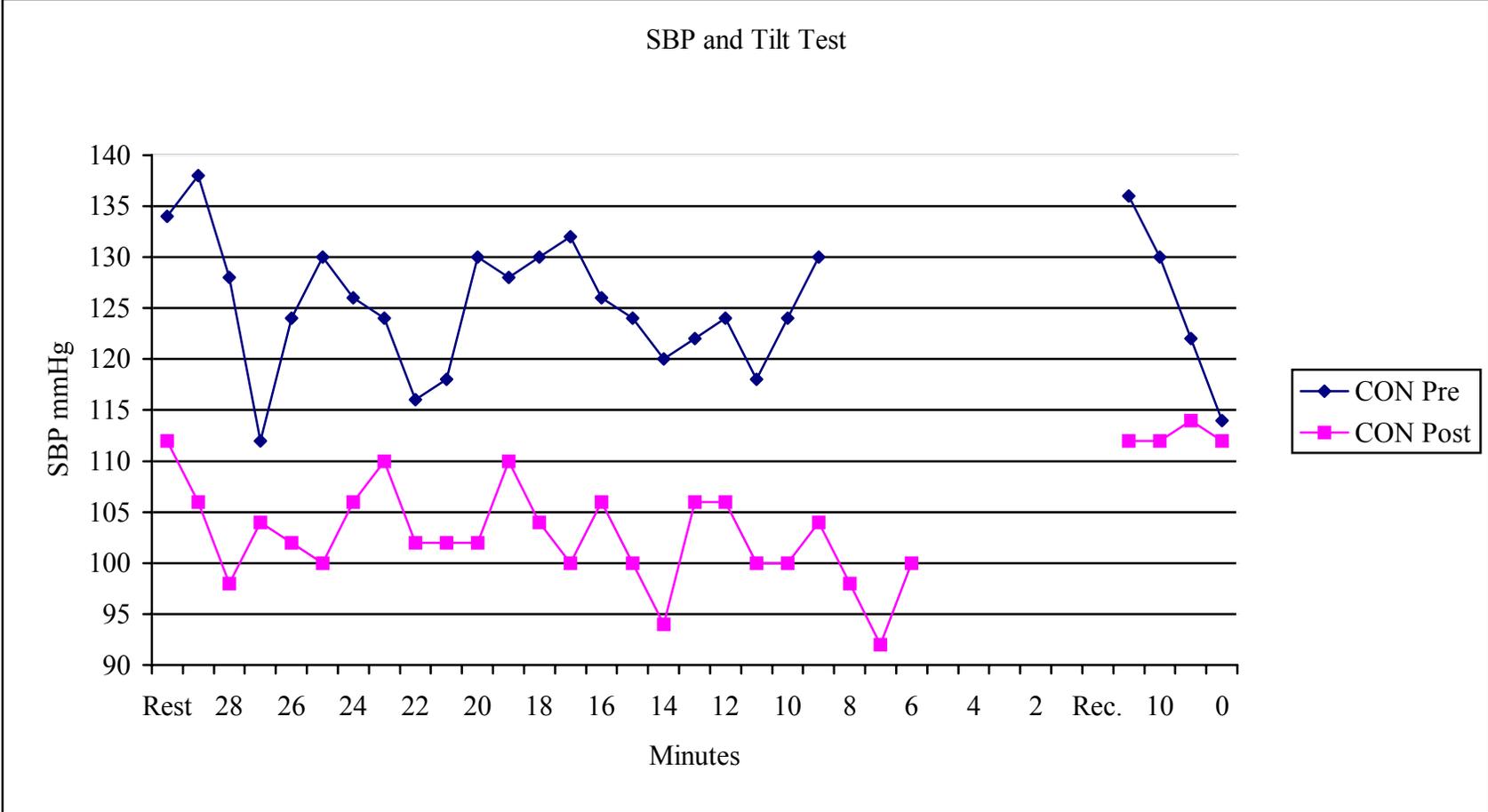
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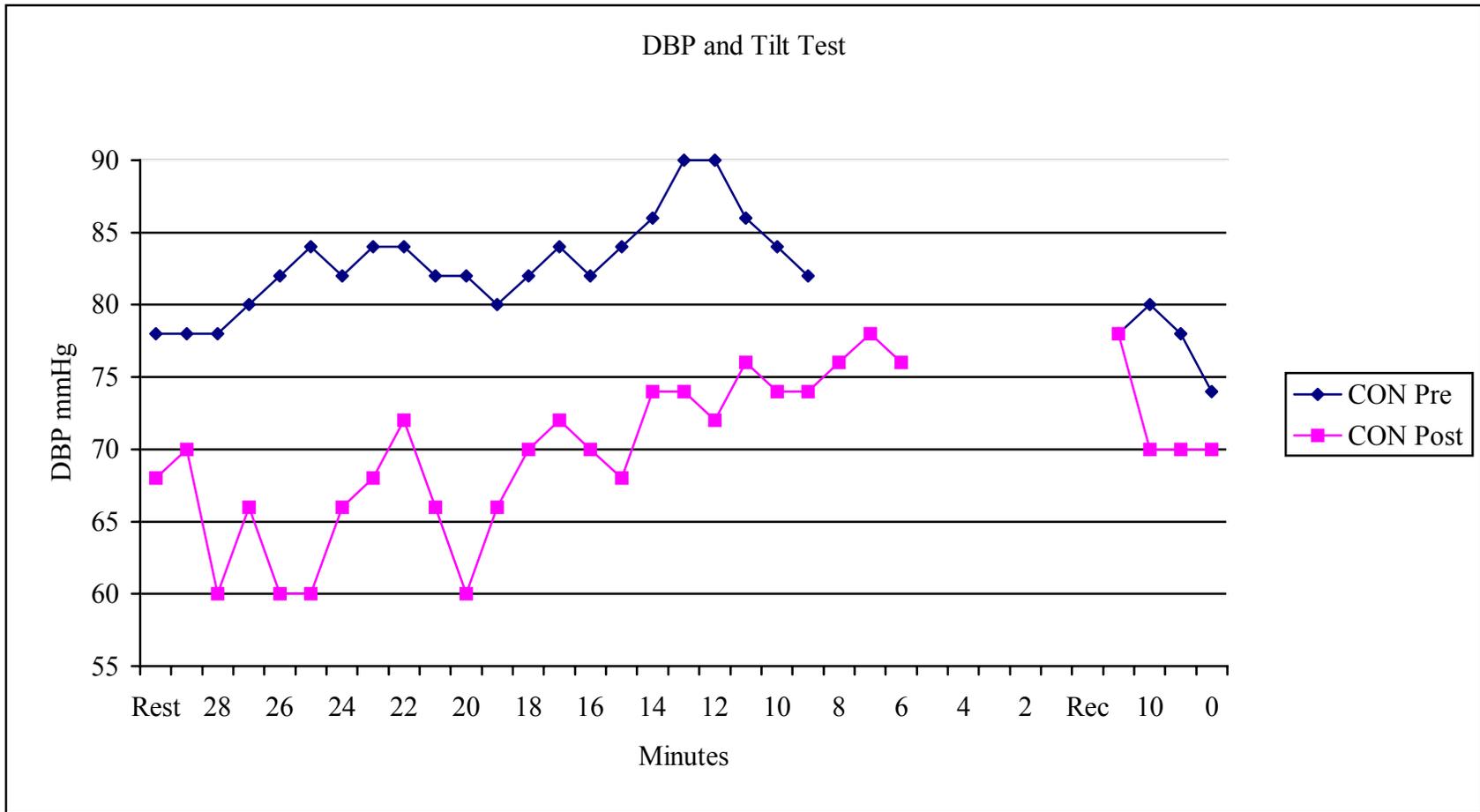
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APPENDIX A
Control Subject Tilt Results

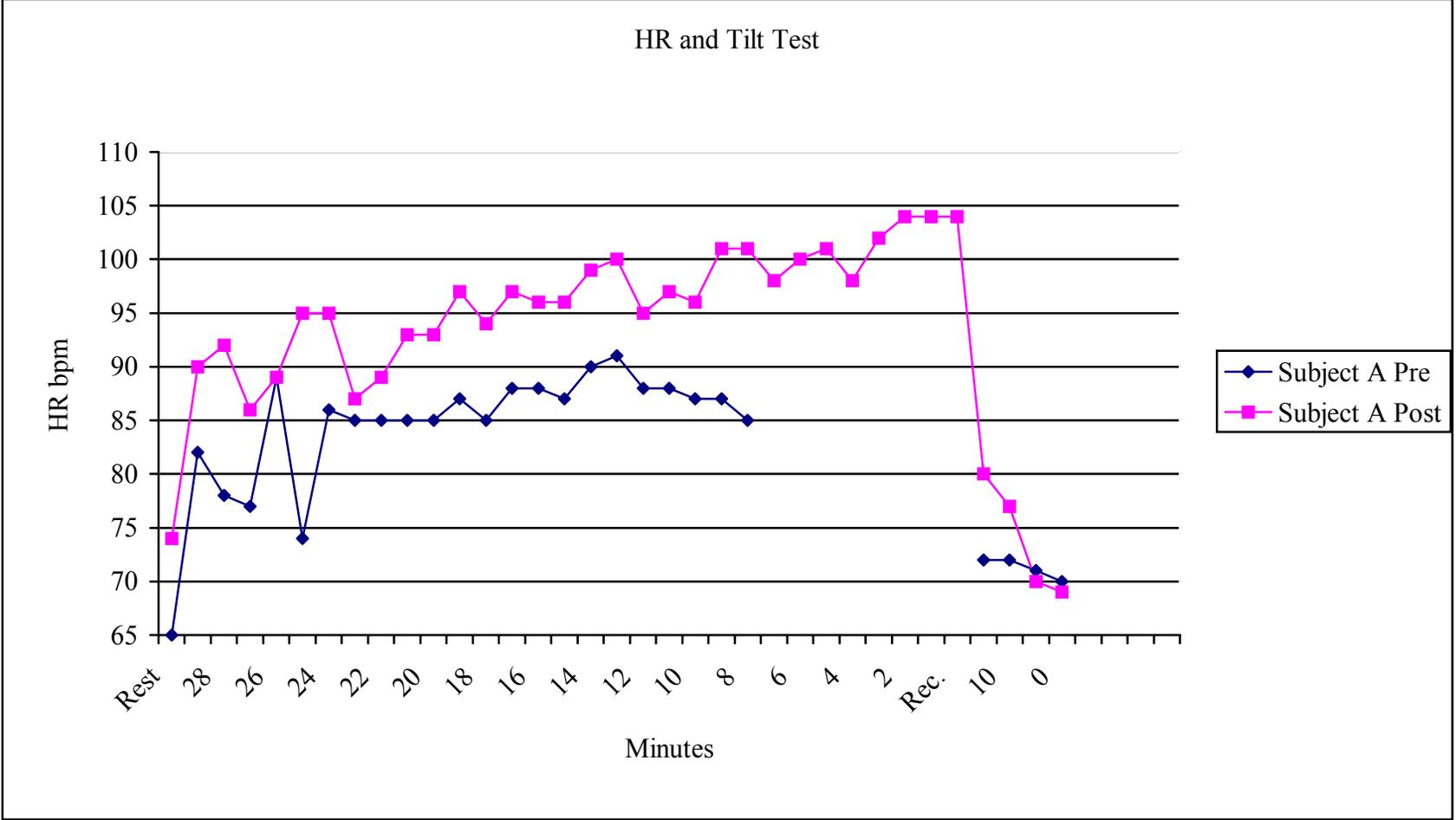


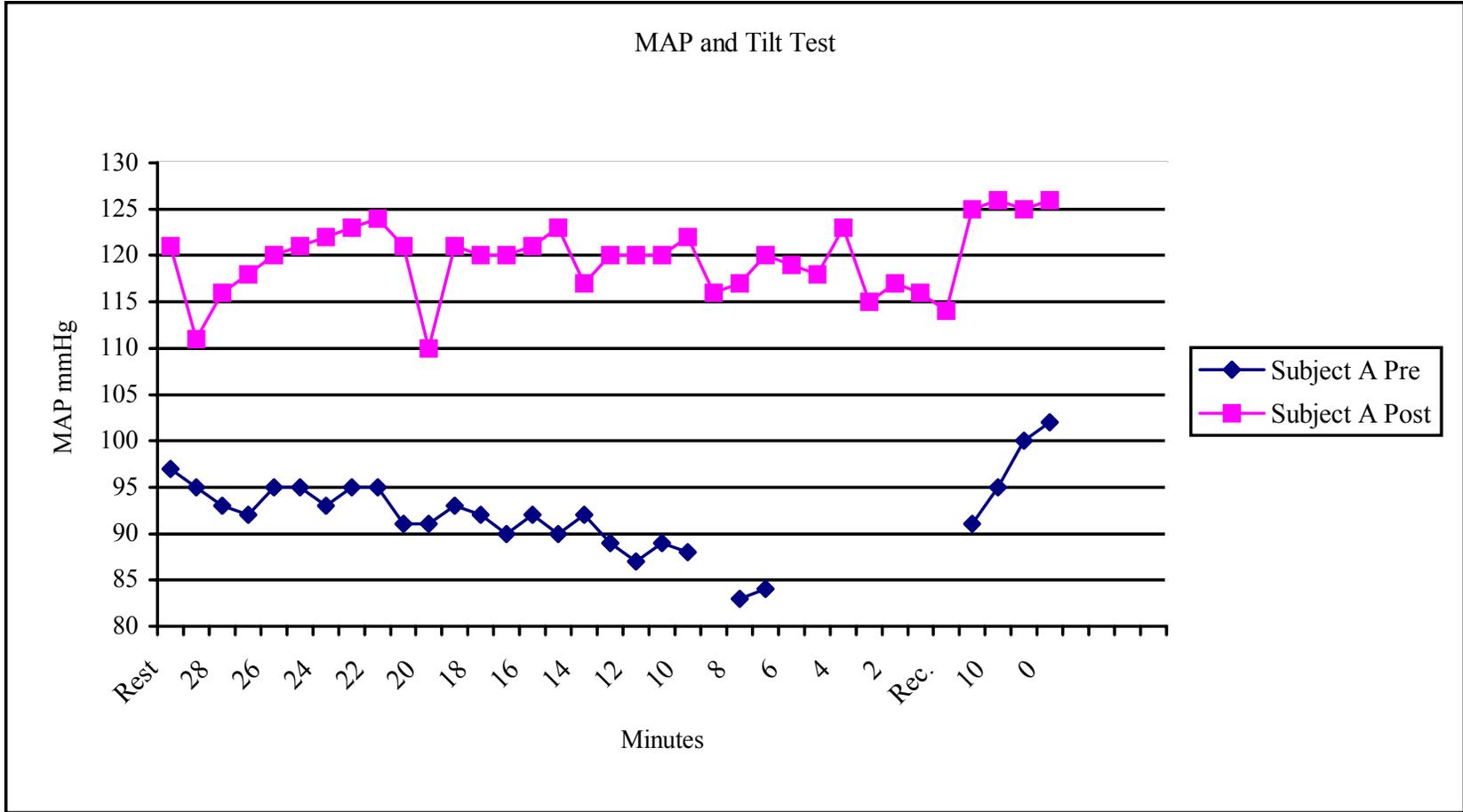


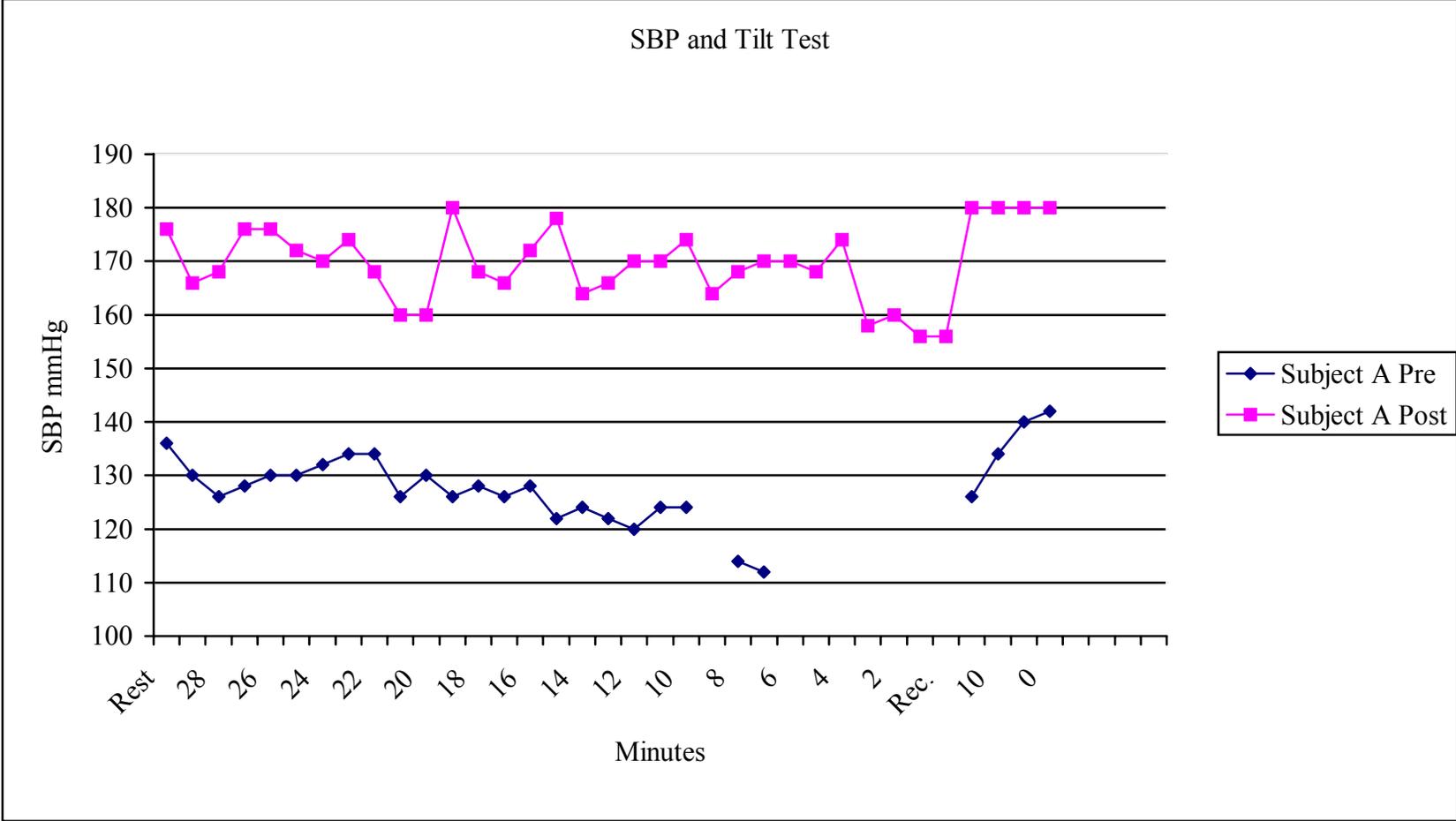


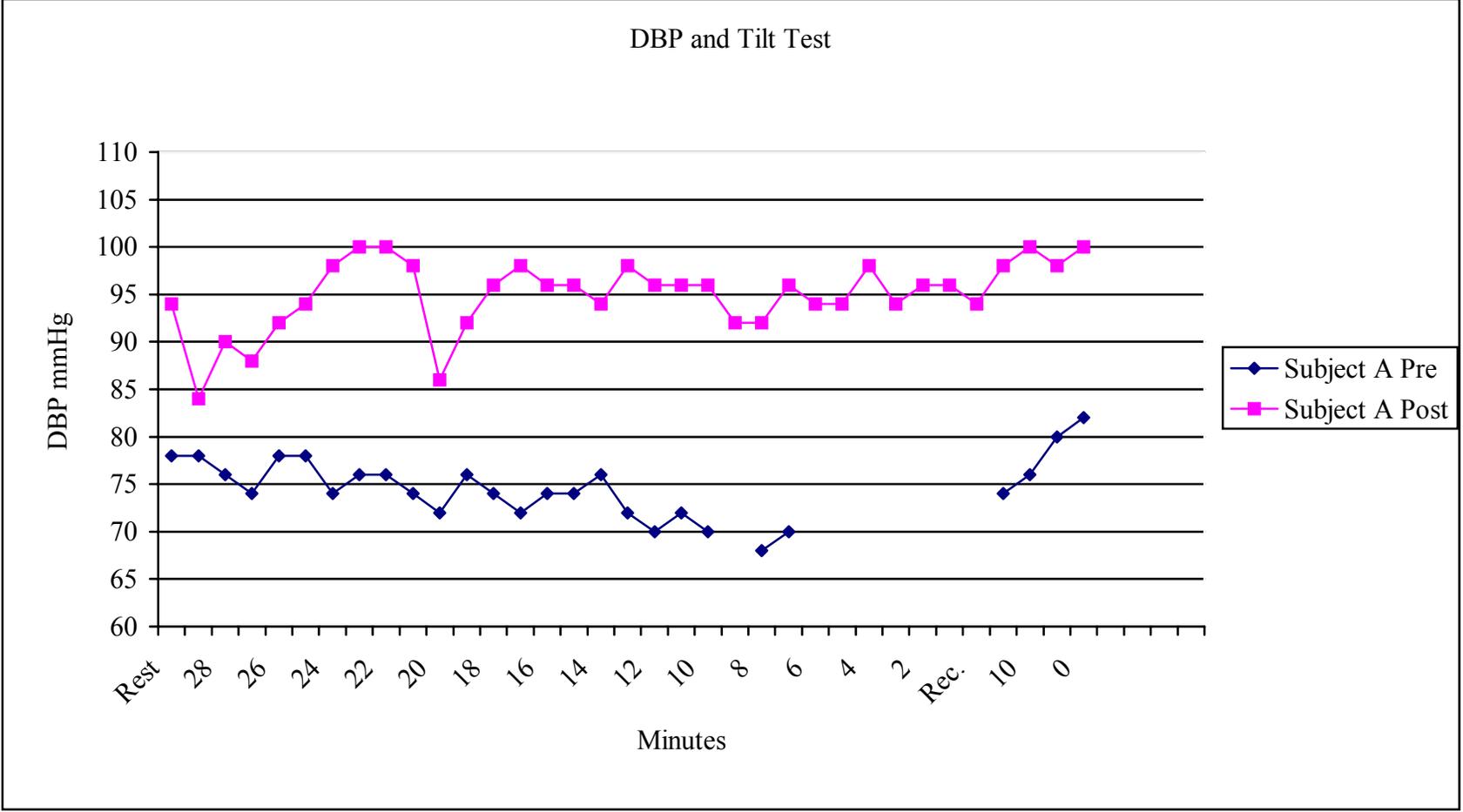


APPENDIX B
Subject A Tilt Results

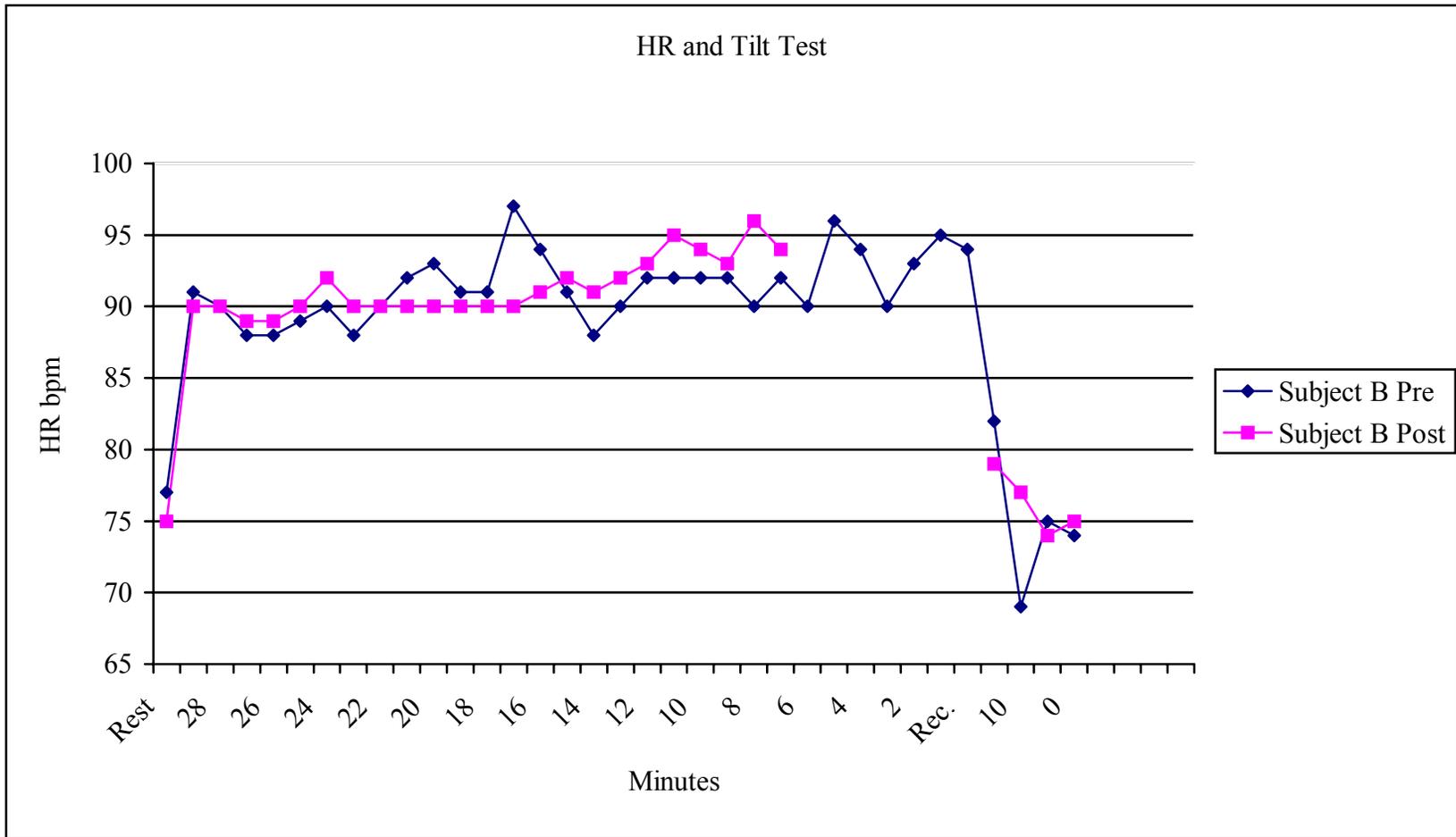


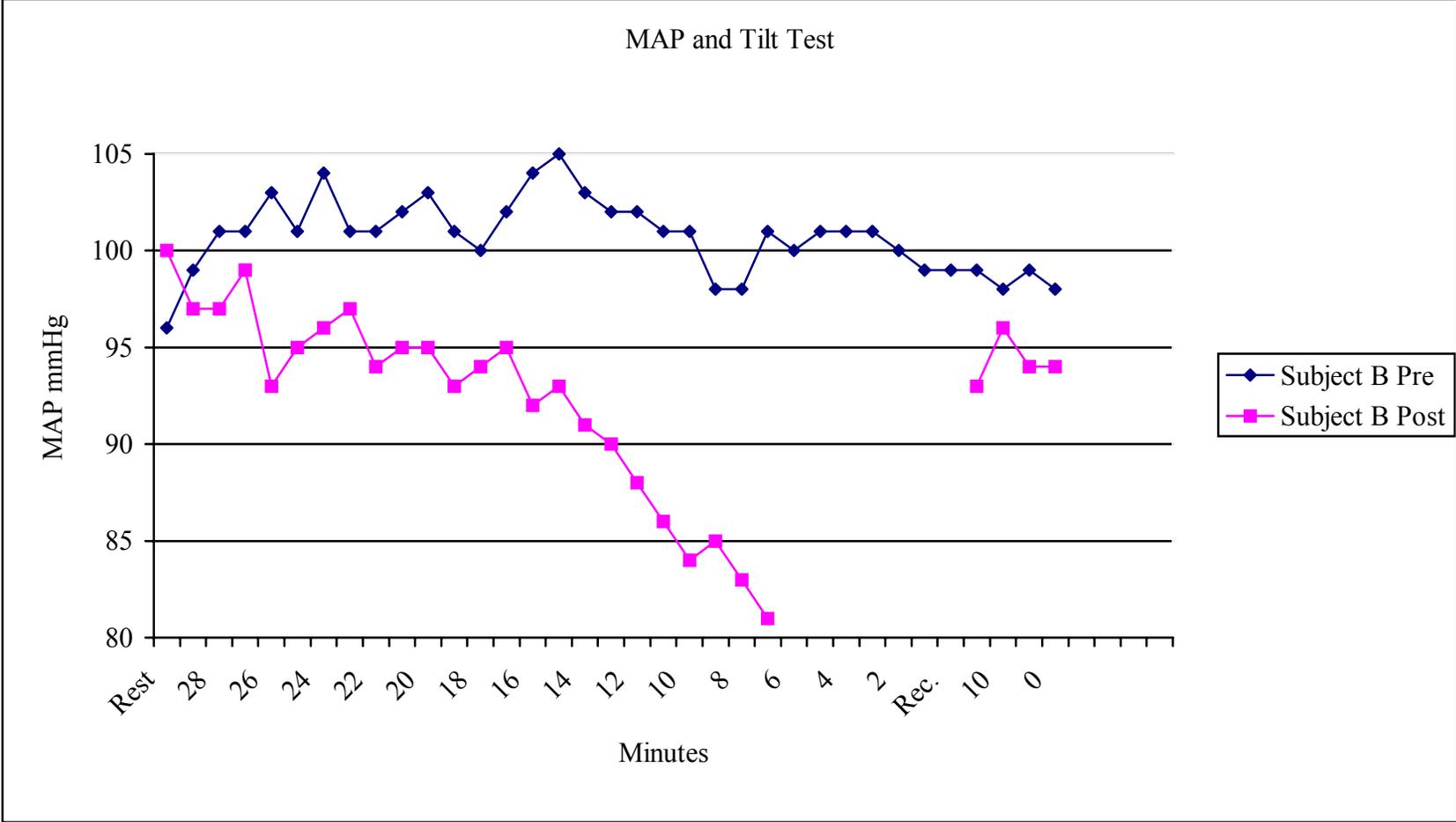


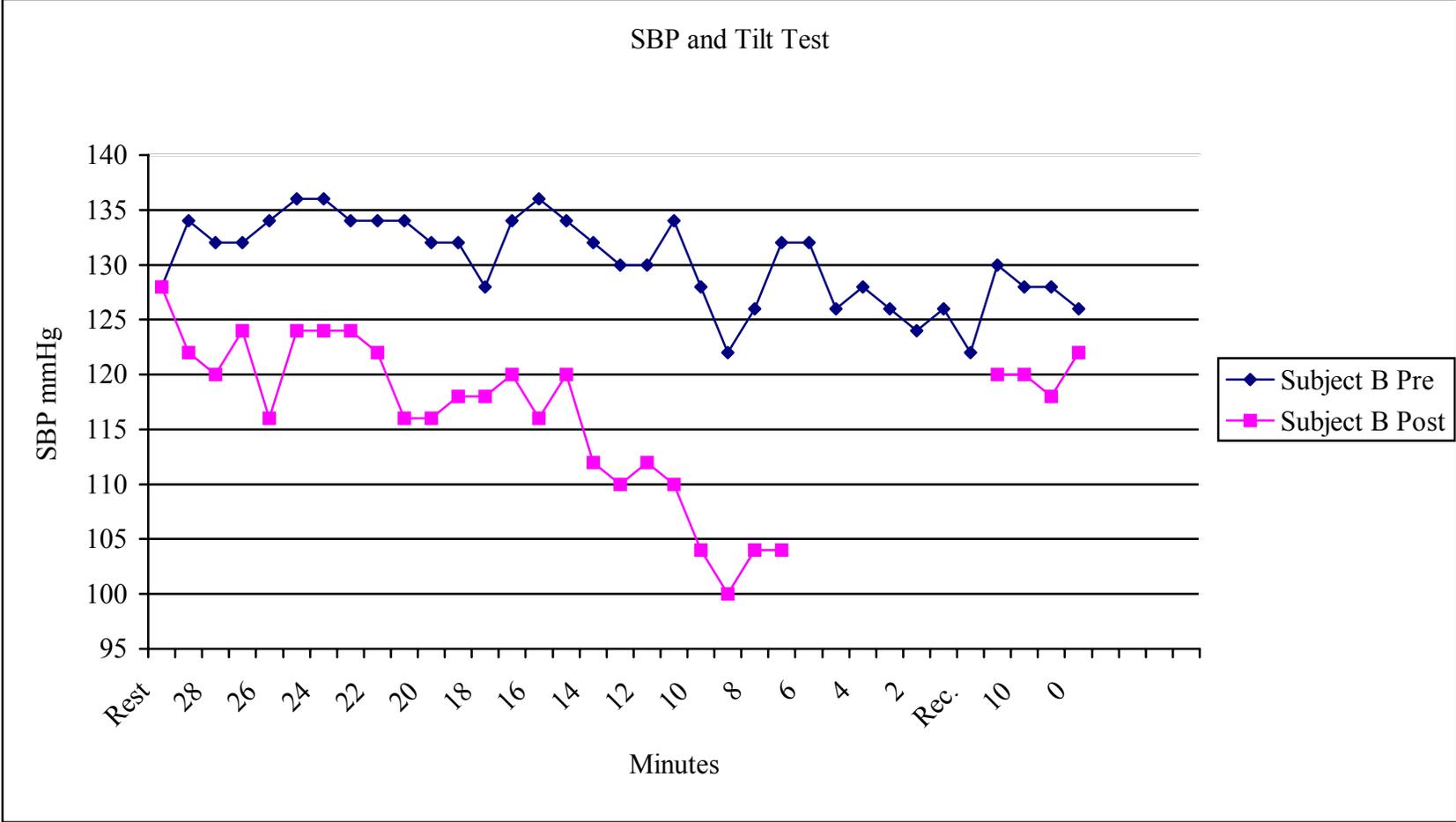


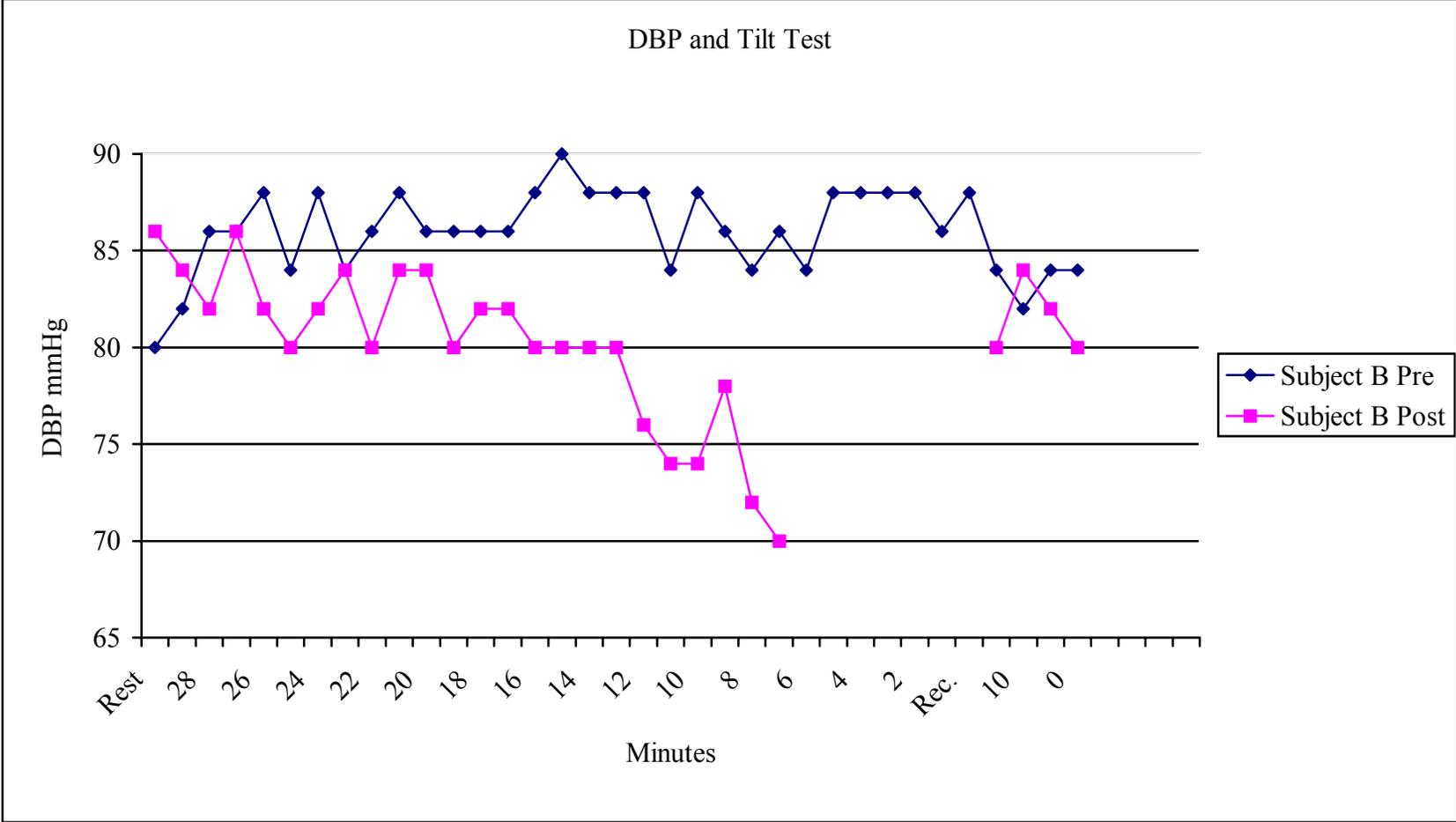


APPENDIX C
Subject B Tilt Results

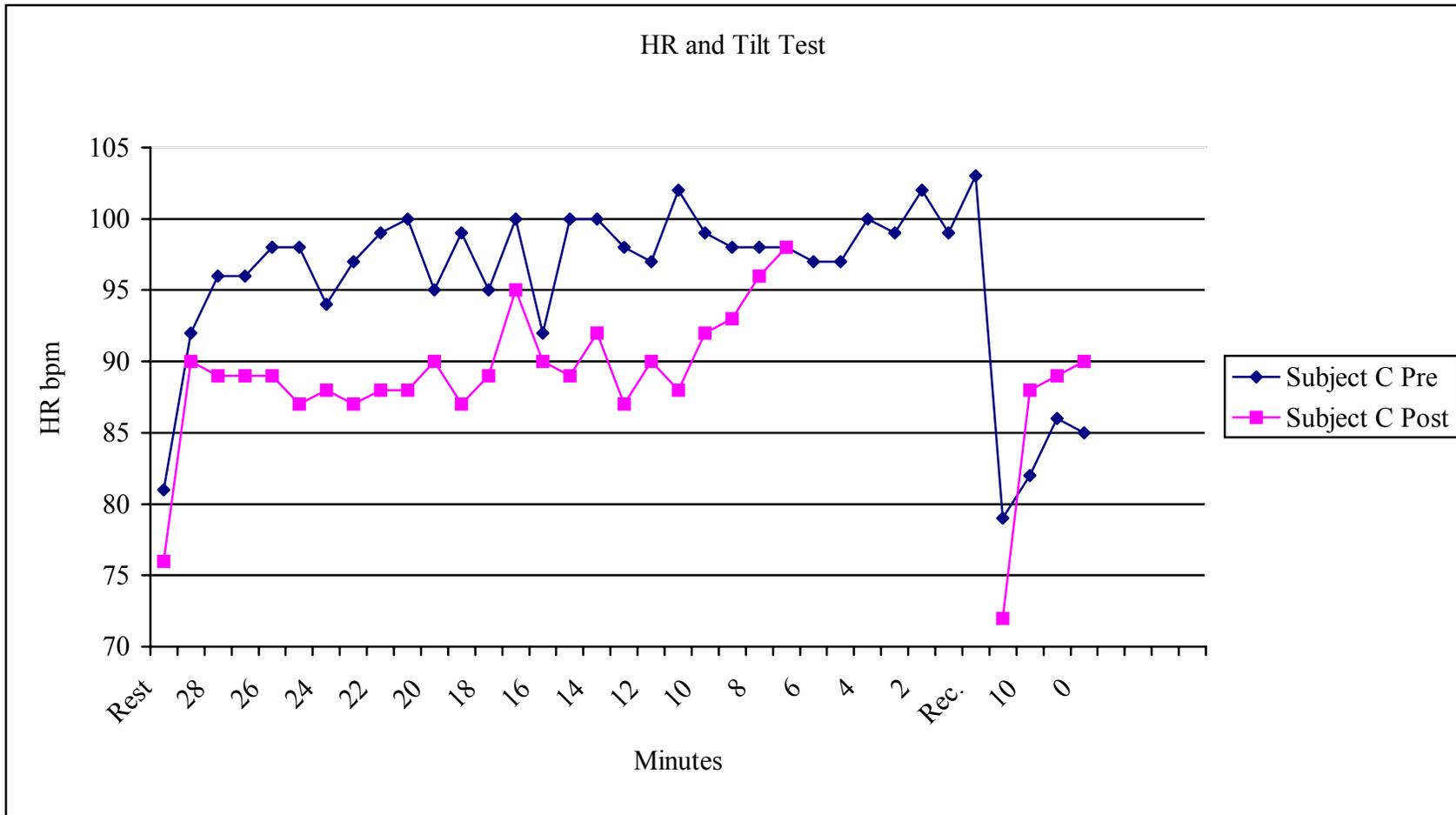


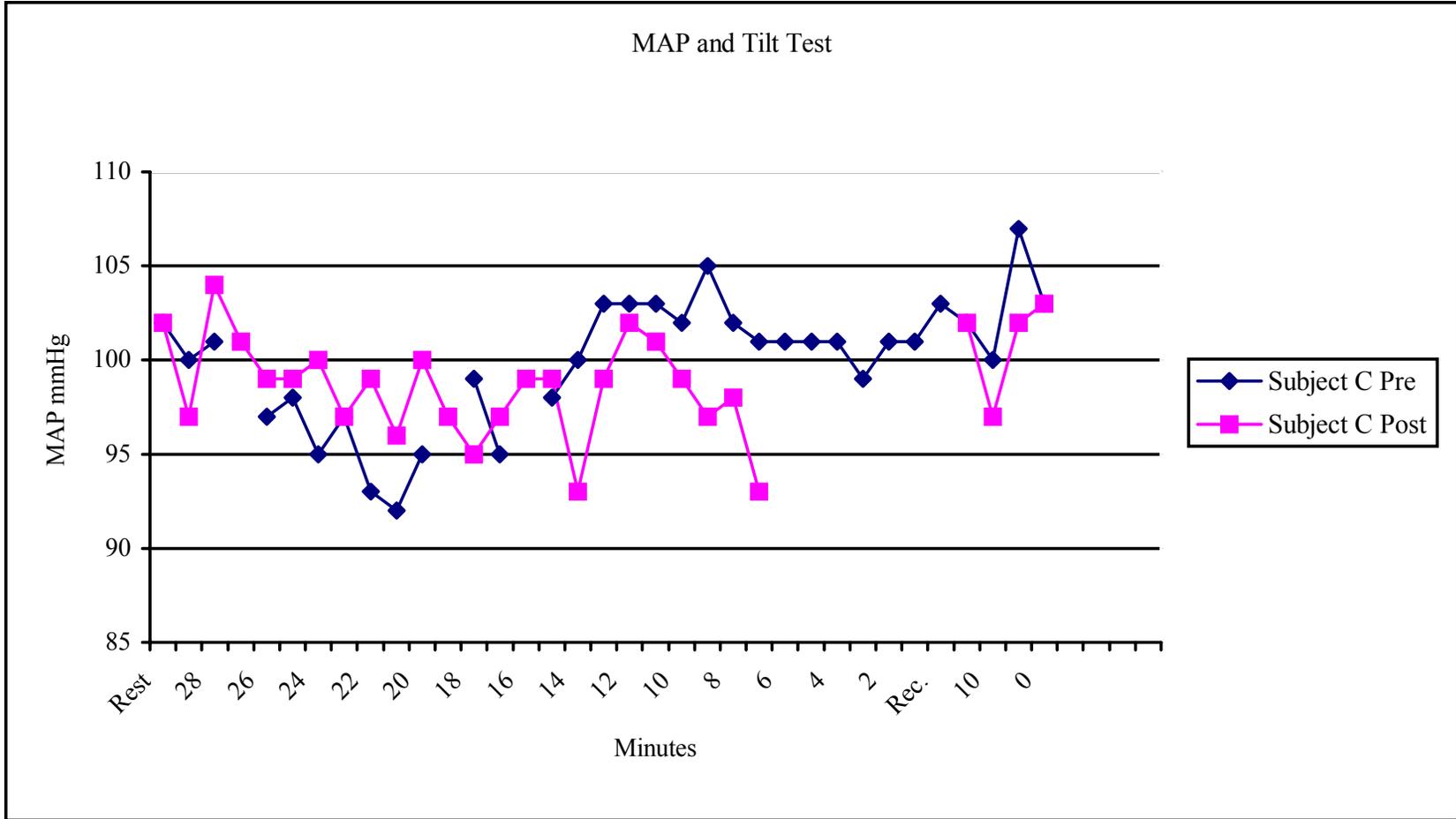


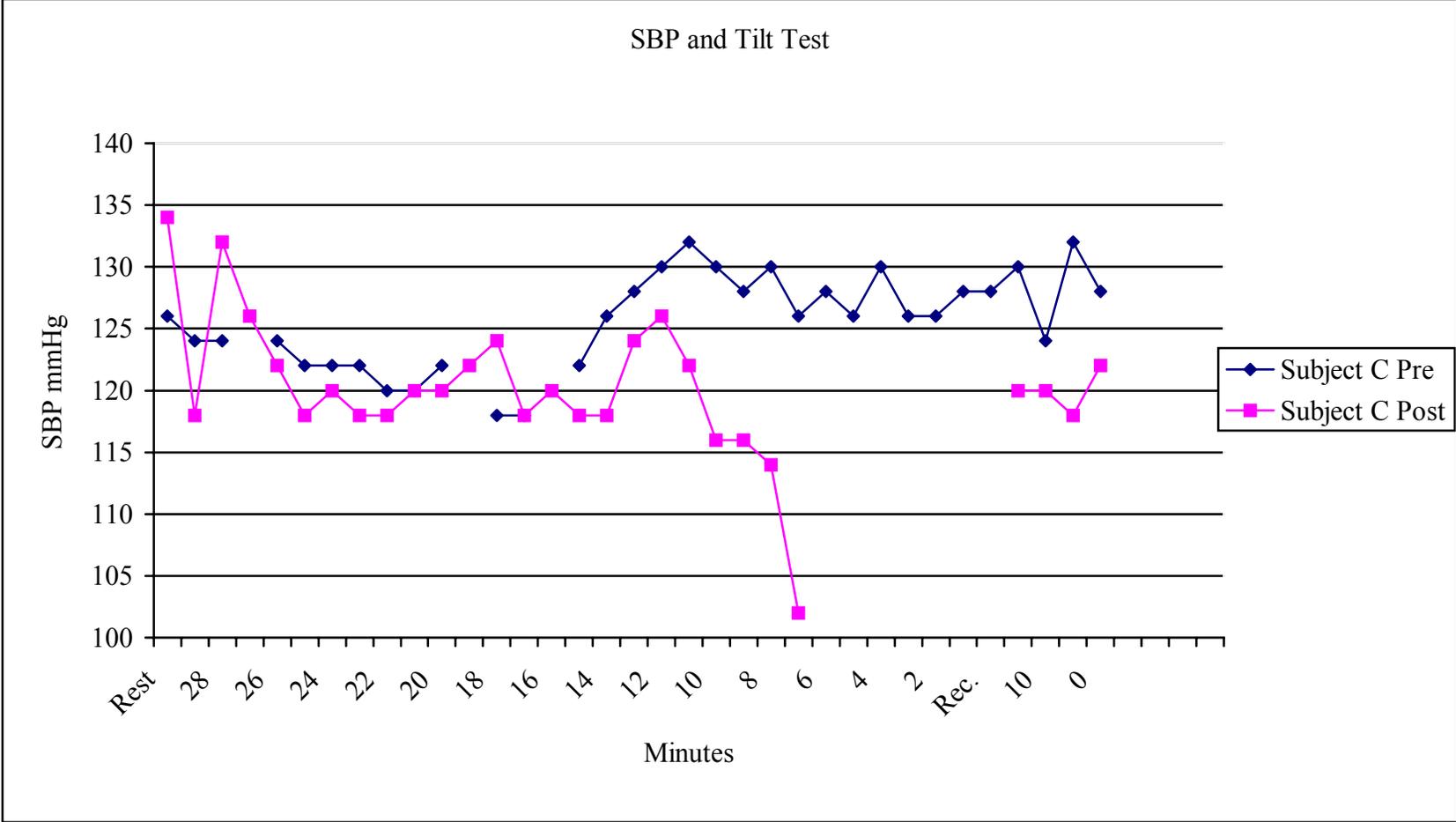


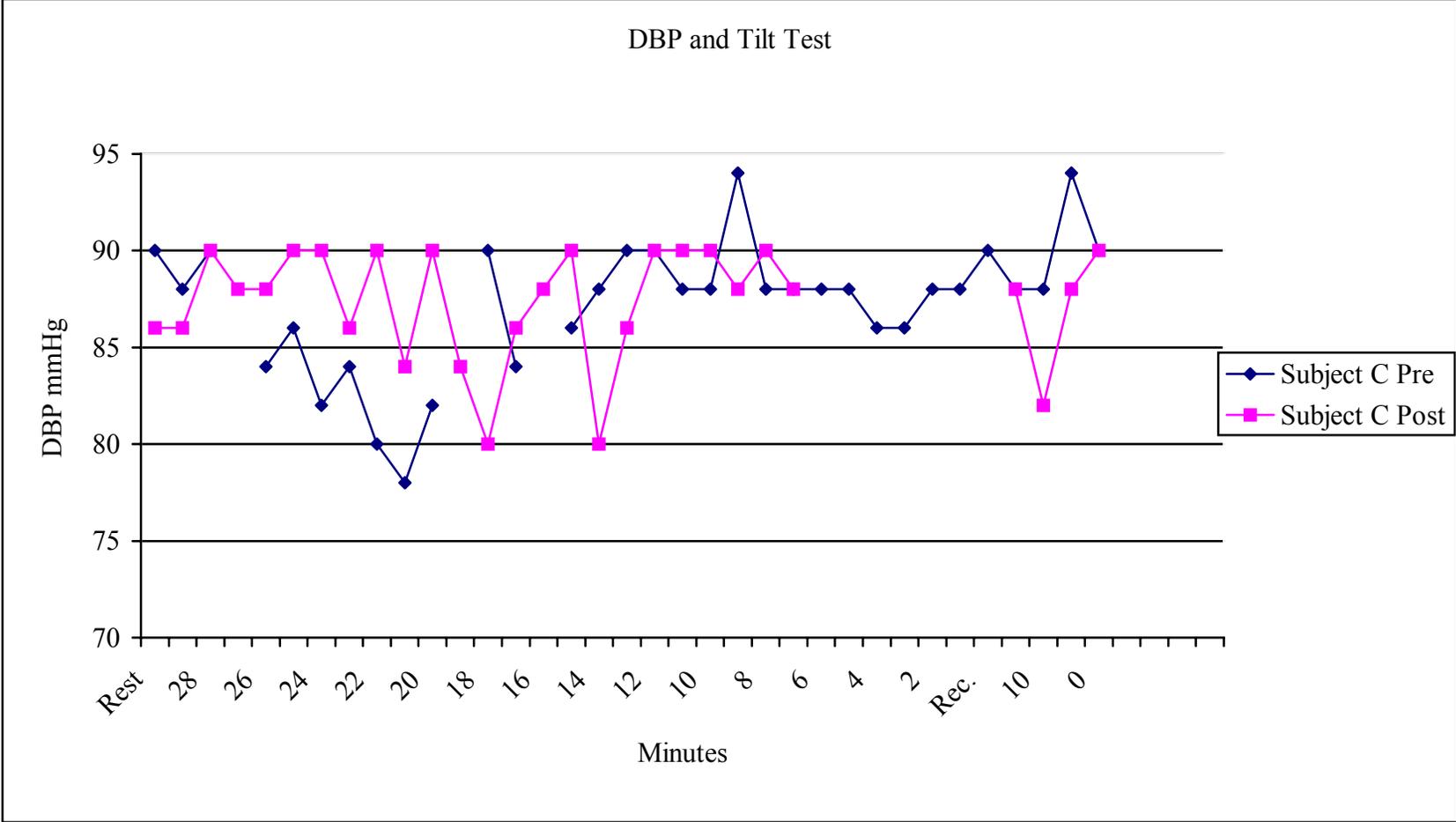


APPENDIX D
Subject C Tilt Results









APPENDIX E
Data of Subjects Completing Tilt Test Period

SUBJECT CHARACTERISTICS FOR SUBJECTS WHO COMPLETED TILT TEST (N=9).

	CON (N=5)	RES (N=4)
Age (yrs)	74 ± 4	65 ± 7*
Height (cm)	162.3 ± 7.1	173.0 ± 5.8*
Weight (kg)	63.3 ± 9.7	77.3 ± 12.9
BMI (kg)	23.9 ± 2.4	25.9 ± 3.8
% Body Fat ^a	34.4 ± 10.9	29.2 ± 13.7
Lean Mass ^a (kg)	38.5 ± 2.4	52.9 ± 17.7

Values are means ± SD.

^a Determined from DEXA.

BMI: Body Mass Index=body weight (kg)/height in meters squared.

* $p \leq 0.05$ indicates significant difference between groups.

STRENGTH MEASUREMENTS FOR SUBJECTS WHO COMPLETED TILT TEST PRE AND POST 12 WEEKS OF TRAINING (N=9).

	CON (N=5)		RES (N=4)	
	Pre	Post	Pre	Post
CP (kg)	31 ± 8	30 ± 7	55 ± 30	66 ± 36* [§]
CP/BW (kg)	.50 ± .15	.48 ± .13	.69 ± .29	.83 ± .35* [§]
LE (kg)	58 ± 10	60 ± 11	69 ± 25	94 ± 37 [‡]
LE/BW (kg)	.92 ± .17	.97 ± .20	.90 ± .35	1.20 ± .36* [§]

Values are means ± SD.

CP= Chest Press; BW= Body Weight; LE= Leg Extension.

CP/BW- Chest Press divided by the appropriate body weight pre and post.

LE/BW= Leg Extension divided by the appropriate body weight pre and post.

* $p \leq 0.05$, indicates significant difference between groups.

[§] $p \leq 0.05$, indicates significant difference between pre and posttest.

[‡] $p = 0.08$, indicates significant difference between groups.

MEASUREMENTS FROM GRADED EXERCISE TEST PRE AND POST 12 WEEKS OF RESISTANCE TRAINING (N=9).

	CON (N=5)		RES (N=4)	
	Pre	Post	Pre	Post
$\dot{V}O_{2\max}$ (ml·kg ⁻¹ ·min ⁻¹)	22.7 ± 6.0	23.0 ± 7.1	26.8 ± 6.1	28.3 ± 7.9
Treadmill Time (min)	12.1 ± 4.3	12.2 ± 5.0	11.6 ± 5.2	12.5 ± 7.0
Max HR (bpm)	138 ± 13	138 ± 15	147 ± 6	152 ± 10
Max RPE	18 ± 2	17 ± 2	19 ± 1	18 ± 1
Max SBP (mmHg)	203 ± 14	194 ± 28	199 ± 7	191 ± 18
Max DBP (mmHg)	91 ± 16	86 ± 15	91 ± 8	83 ± 15

Values are means ± S.D.

$\dot{V}O_{2\max}$: Maximal oxygen uptake.

Max HR: Maximum Heart Rate during $\dot{V}O_{2\max}$ test.

Max RPE: Maximum Rating of Perceived Exertion during $\dot{V}O_{2\max}$ test.

Max SBP: Maximum Systolic Blood Pressure during $\dot{V}O_{2\max}$ test.

Max DBP: Maximum Diastolic Blood Pressure during $\dot{V}O_{2\max}$ test.

BODY COMPOSITION^a FOR SUBJECTS WHO COMPLETED TILT TEST PRE AND POST 12 WEEKS OF RESISTANCE TRAINING (N=9).

	CON (N=5)		RES (N=4)	
	Pre	Post	Pre	Post
BW (kg)	63.3 ± 9.7	62.5 ± 8.9	77.3 ± 12.9	77.2 ± 14.1
BMI (kg)	23.9 ± 2.4	23.6 ± 2.3	25.9 ± 3.8	25.7 ± 4.2
% Body Fat	34.4 ± 10.9	30.7 ± 7.7	29.1 ± 13.7	26.7 ± 16.0
Bone Density ^a (g/cm ²)	0.976 ± .092	1.003 ± .082	1.186 ± .163	1.200±.156*
Lean Mass ^a (kg)	38.5 ± 2.4	39.8 ± 1.4	52.9 ± 17.7	56.0 ± 17.5*

Values are means ± S.D.

^a Determined from DEXA.

BW: Body Weight

BMI: Body Mass Index=body weight (kg)/height in meters squared.

*p≤0.05 indicates significant difference between groups.

VITA

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 Cardiac Rehabilitation, 2000-present